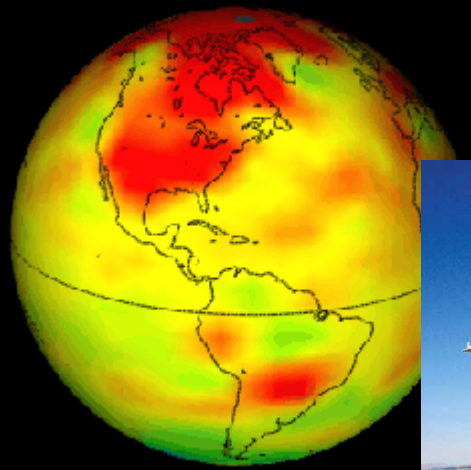
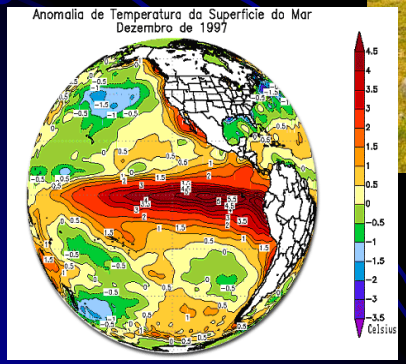
WMO/UNISDR Expert Group Meeting on Agricultural Drought Index

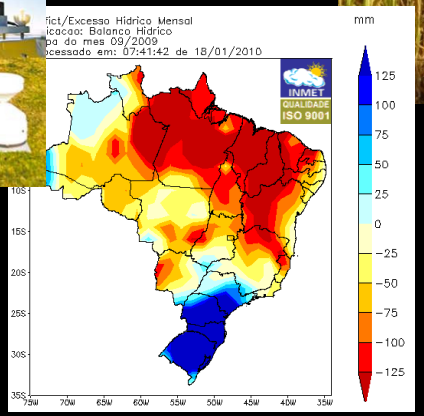
Murcia, Spain – 02 to 04 June 2010

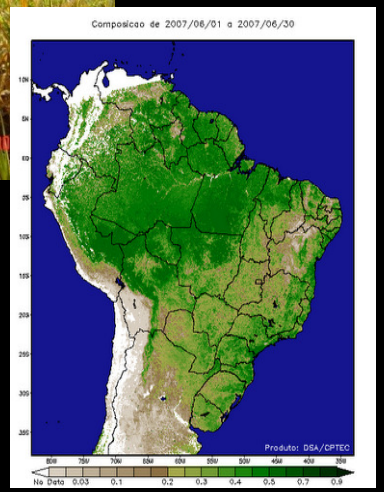
Agricultural Drought Indices in Current Use in Brazil

Prof. Paulo C. Sentelhas
ESALQ - University of São Paulo









WMO/UNISDR Expert Group Meeting on Agricultural Drought Index

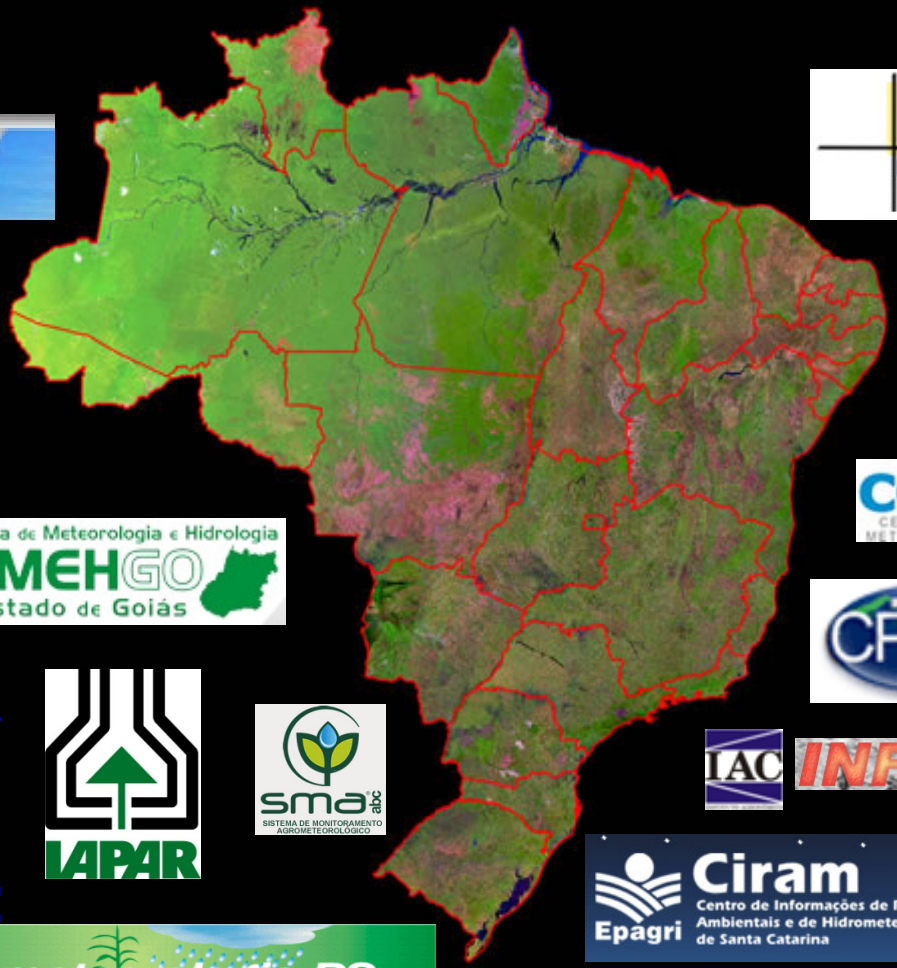
Murcia, Spain – 02 to 04 June 2010

Agricultural Drought Indices in Current Use in Brazil

Presentation Outline

- National and Regional Agrometeorological Services in Brazil
- Meteorological x Agricultural Drought Indices in Current Use
- Water Balance based Drought Indexes
- Strengths, Weaknesses and Limitations of AgDI
- Final Remarks

National and Regional Agrometeorological Services in Brazil



Agritempo

FUNCEME

INMET 100

ITEP INSTITUTO DE TECNOLOGIA DE PERNAMBUCO

cemba CENTRO ESTADUAL DE METEOROLOGIA DA BAHIA

Sistema de Meteorologia e Hidrologia SIMEHGO do Estado de Goiás

CPTEC

IAPAR

sma abc SISTEMA DE MONITORAMENTO AGROMETEOROLÓGICO

IAC

INFOSECA

Epagri Ciram Centro de Informações de Recursos Ambientais e de Hidrometeorologia de Santa Catarina

Agrometeorologia RS

National and Regional Agrometeorological Services in Brazil

Brazil has 3 National M&HS:

INMET 100

Agritempo

CPTEC

Some states have their own Regional M&HS:

Sistema de Meteorologia e Hidrologia SIMEHGO do Estado de Goiás

Agrometeorologia RS

FUNCEME

IAPAR

sma abc SISTEMA DE MONITORAMENTO AGROMETEOROLÓGICO

Epagri Ciram Centro de Informações de Recursos Ambientais e de Hidrometeorologia de Santa Catarina

cemba CENTRO ESTADUAL DE METEOROLOGIA DA BAHIA

ITEP INSTITUTO DE TECNOLOGIA DE PERNAMBUCO

IAC

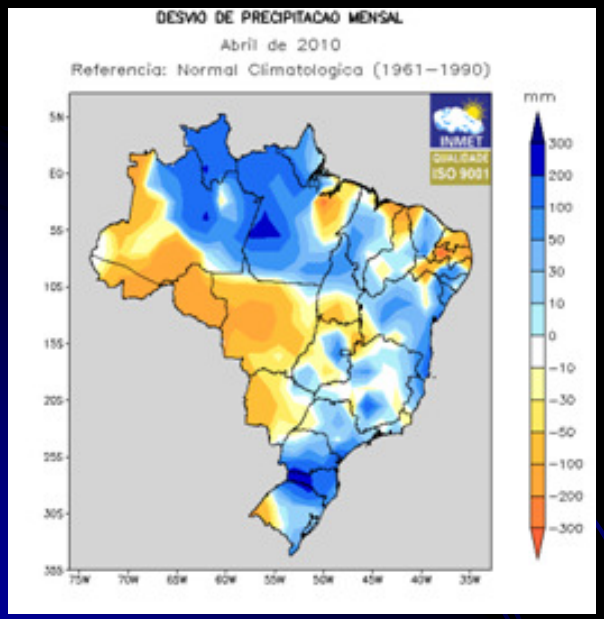
INFOSECA

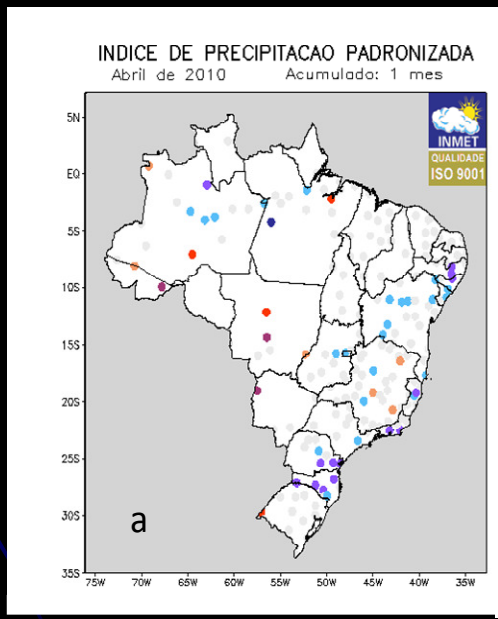
Meteorological x Agricultural Drought Indices in Current Use

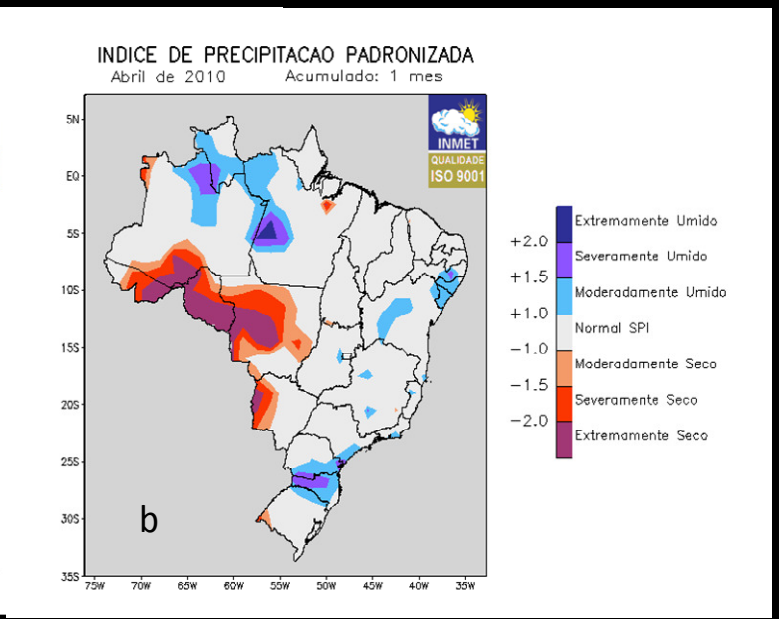
METEOROLOGICAL DROUGHT INDEXES

Based on precipitation data, its variability and statistics.

Most used in Brazil are: Rainfall Anomaly and SPI





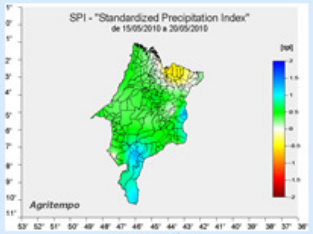


Other examples of Agricultural Drought Monitoring in Brazil

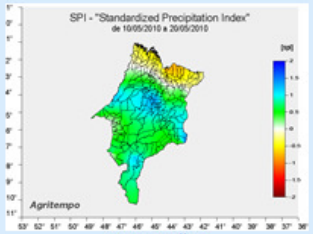
Agritempo

SPI for 5 days to 6 months

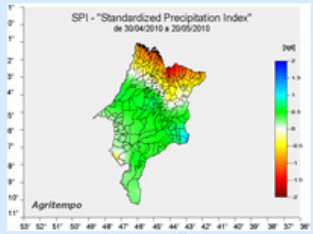
Mapas de Índice de Seca - MA



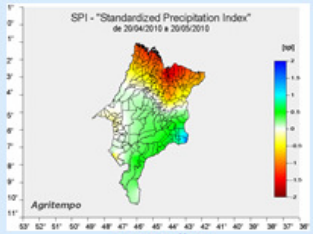
SPI 5 dias



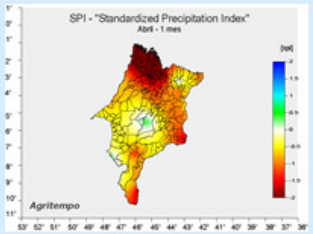
SPI 10 dias



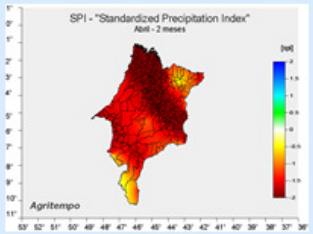
SPI 20 dias



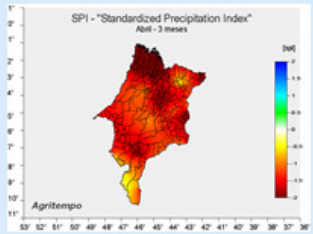
SPI 30 dias



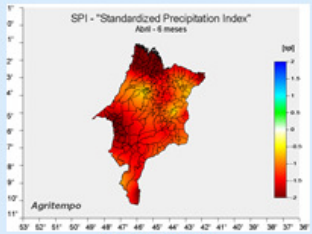
SPI 1 mes



SPI 2 meses



SPI 3 meses



SPI 6 meses

Other examples of Agricultural Drought Monitoring in Brazil

INFOSECA

CENTRO DE MONITORAMENTO E MITIGAÇÃO DE SECA E ADVERSIDADES HIDROMETEOROLÓGICAS

FINALIDADE :: OBJETIVO :: EQUIPE :: COLABORADORES :: SUPORTE :: DESENVOLVIMENTO

Índice Padronizado de Precipitação - Abril - 2010

SPI 30 Dias

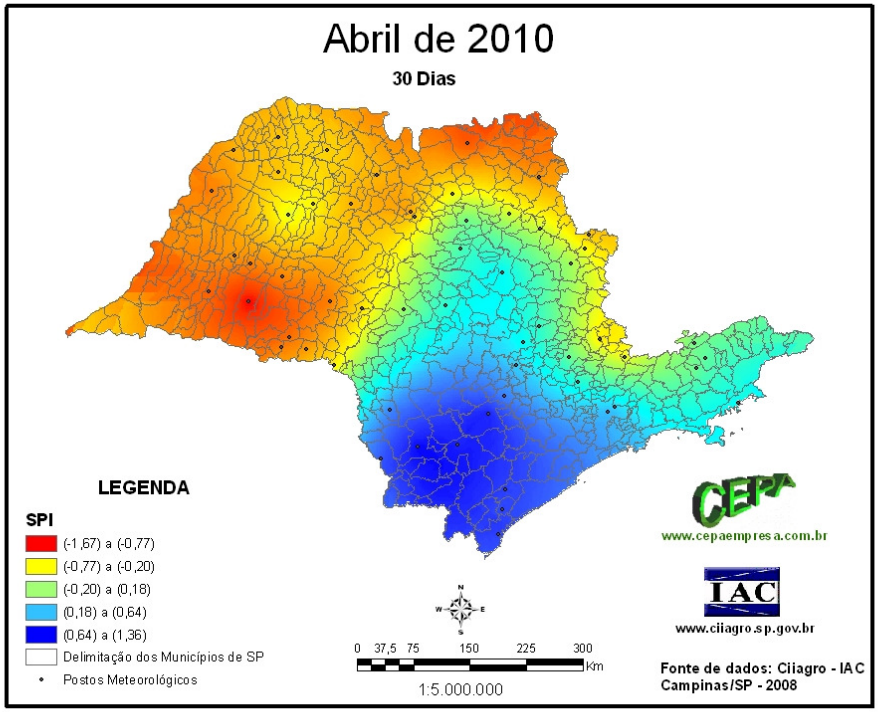
SPI 3 Meses

SPI 6 Meses

SPI 9 Meses

SPI 12 Meses

SPI 24 Meses



AGRICULTURAL DROUGHT INDEXES

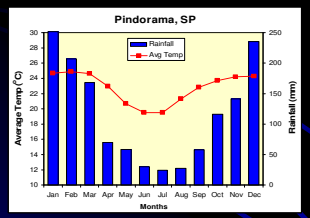
More complex than Meteorological Indexes, since they depend on:

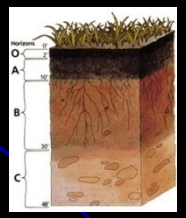
Climate (Rainfall and Evapotranspiration)

Soil (Holding Capacity and Moisture)

Crop (Species, Variety, Root depth and Phenological Phase)

Crop Management (Sowing dates, Crop rotation, Irrigation, No tillage, Intercropping)



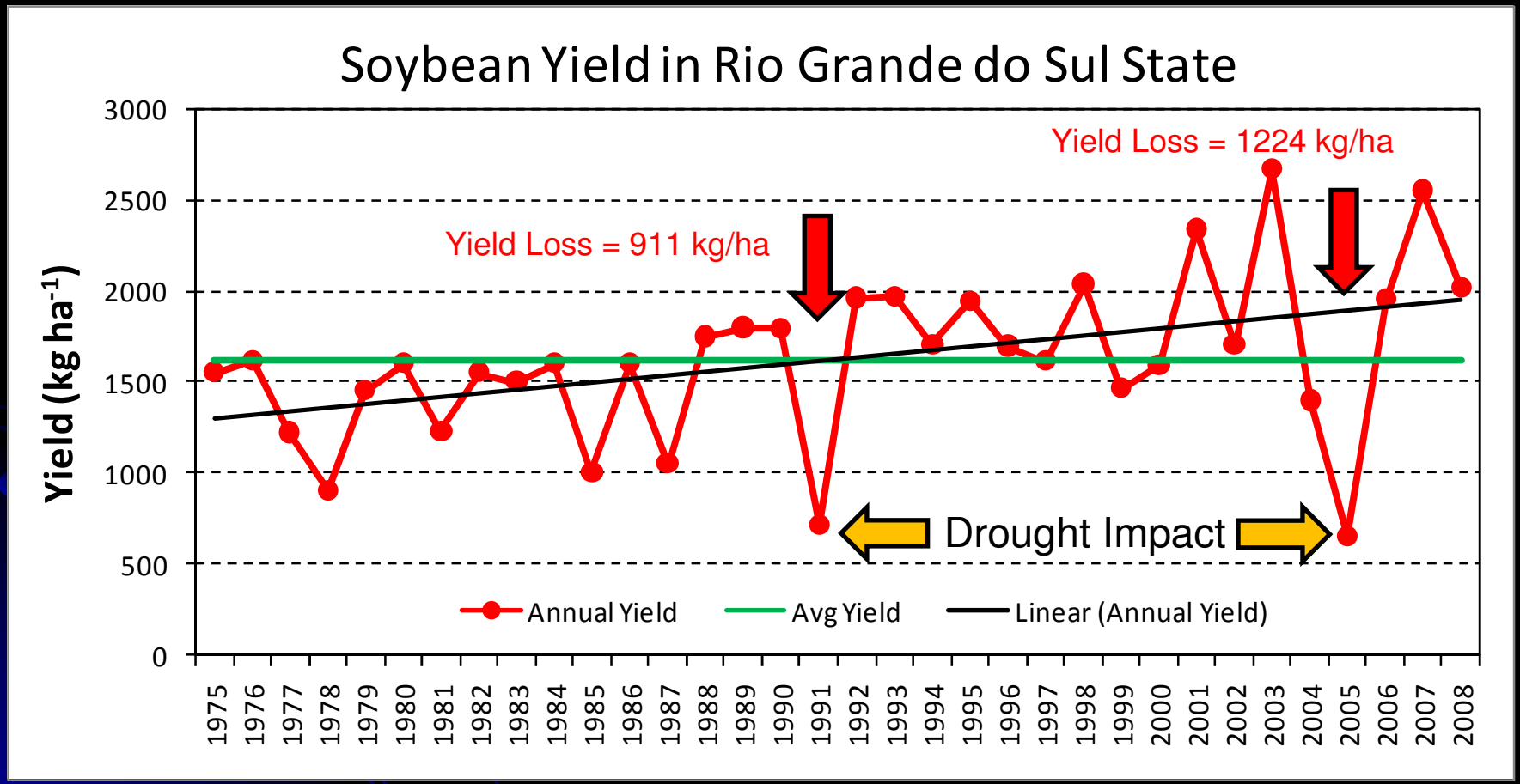


The combination of these factors leads to different impacts

to agriculture when a drought occurs, making difficult to

decide which Is the best index to quantify the drought for agriculture

Drought Impact on Soybean Crop in Southern Brazil

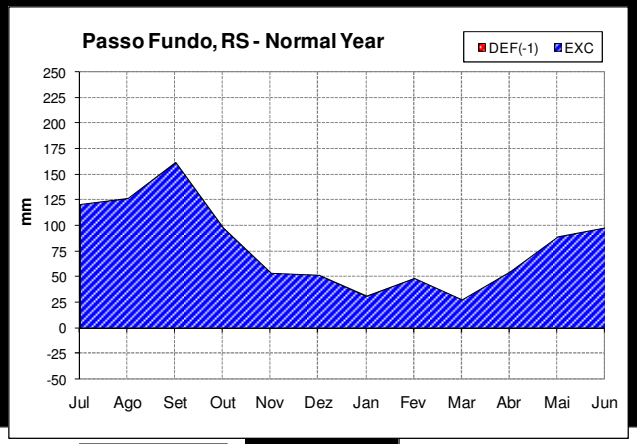


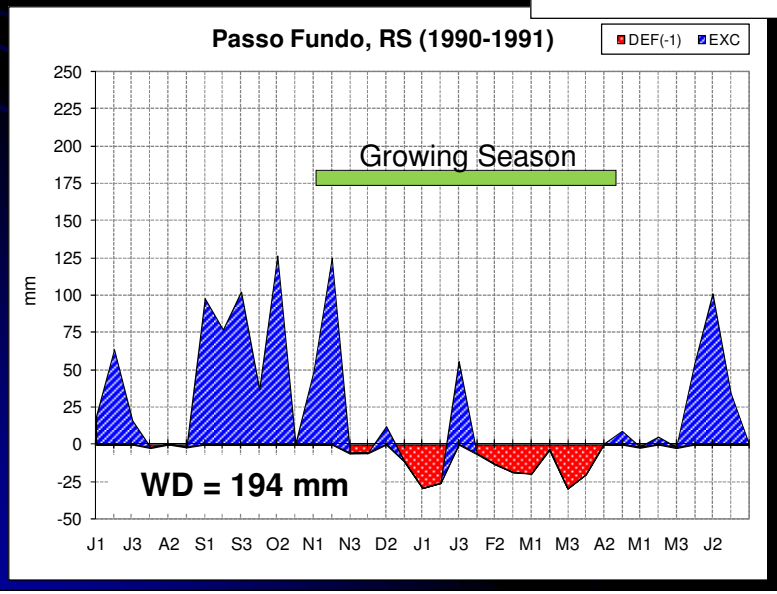
AGRICULTURAL DROUGHT INDEXES

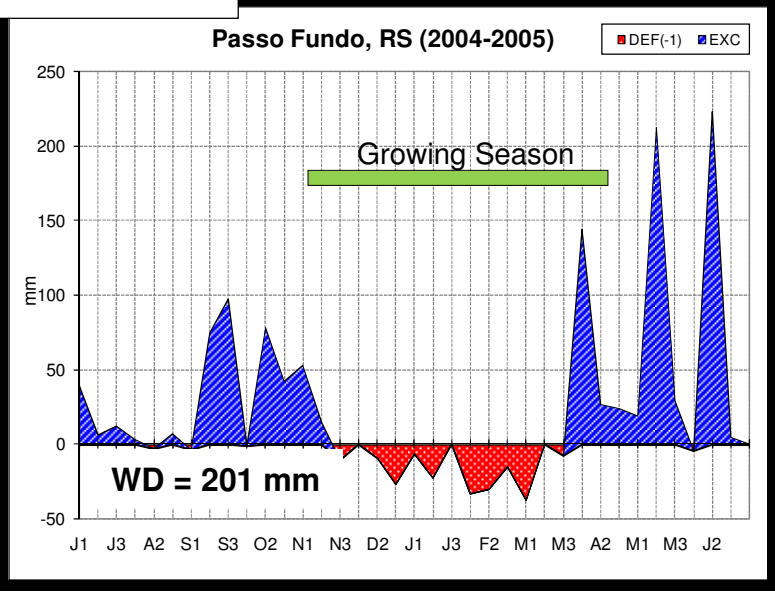
The most used Agricultural Drought Index used in Brazil is

Water Deficiency based on the Climatological Water Balance (T&M, 1955)

SWHC = 50 mm



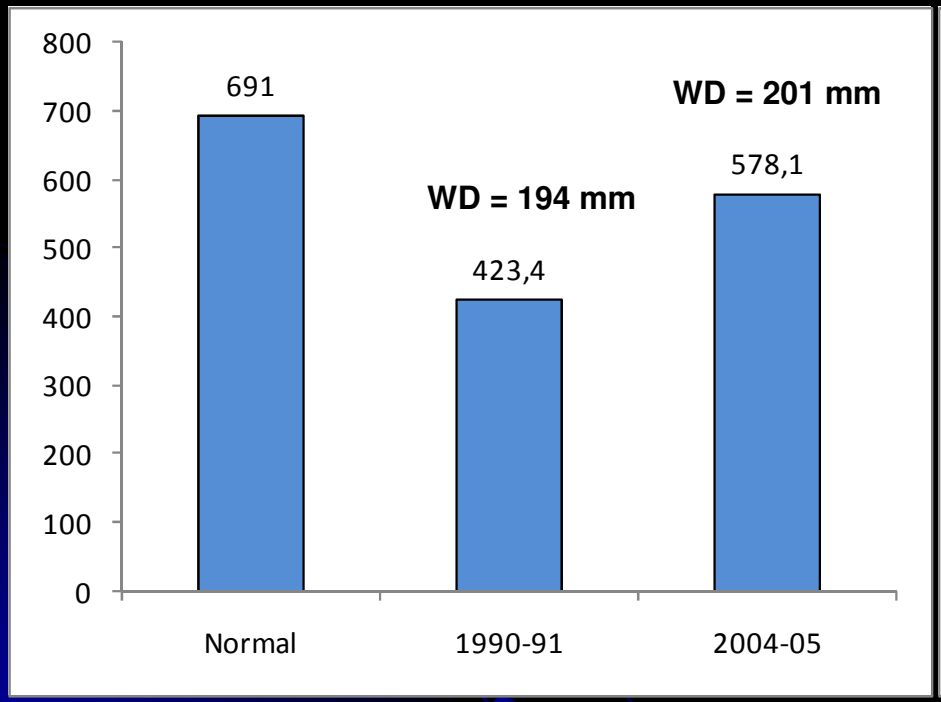




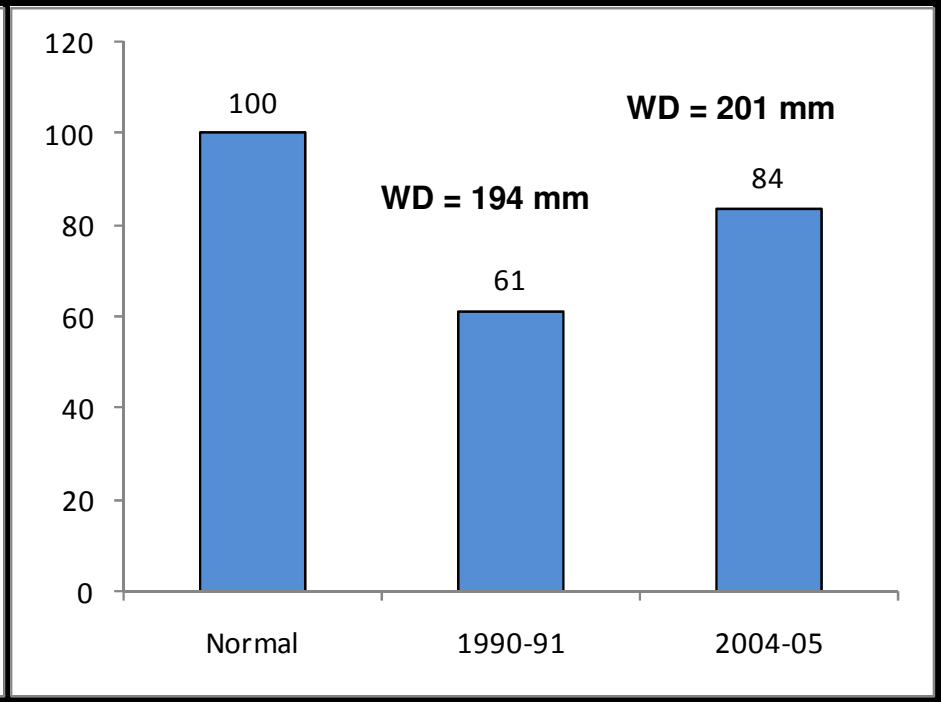
Drought Monitoring

Almost the same water deficiency can be observed for different amounts of rainfall during the growing season

Total Rainfall – Growing Season



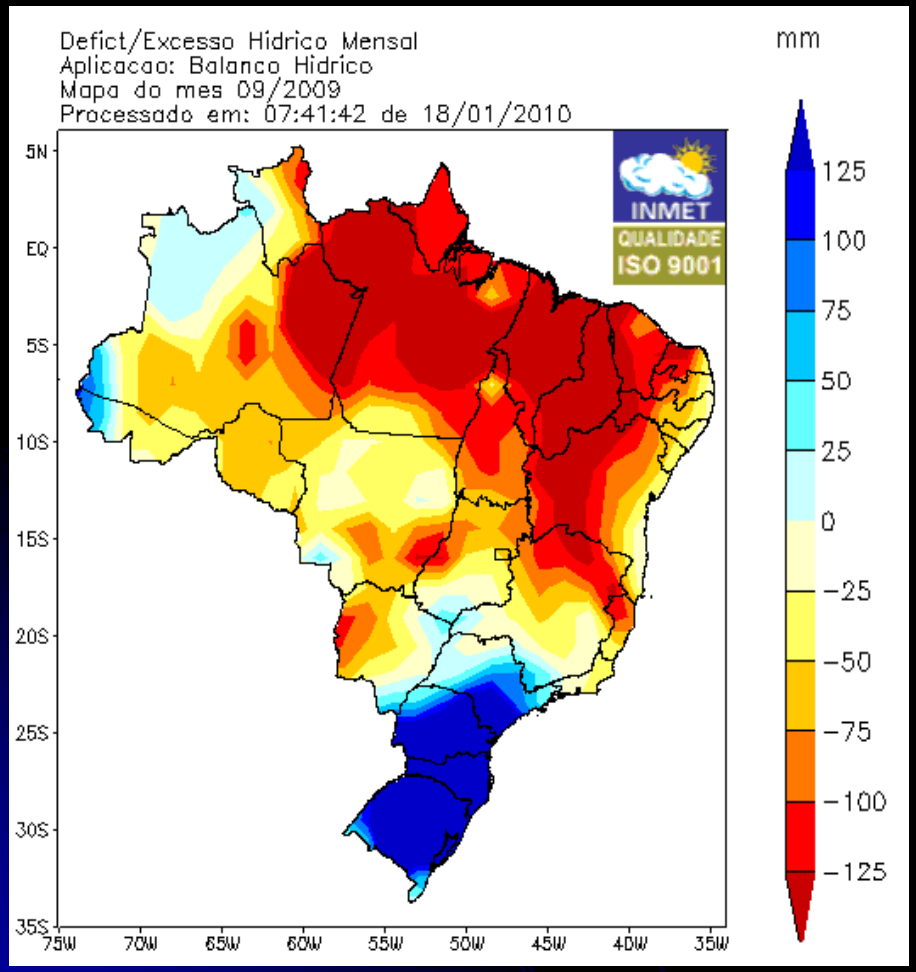
% of the Normal– Growing Season

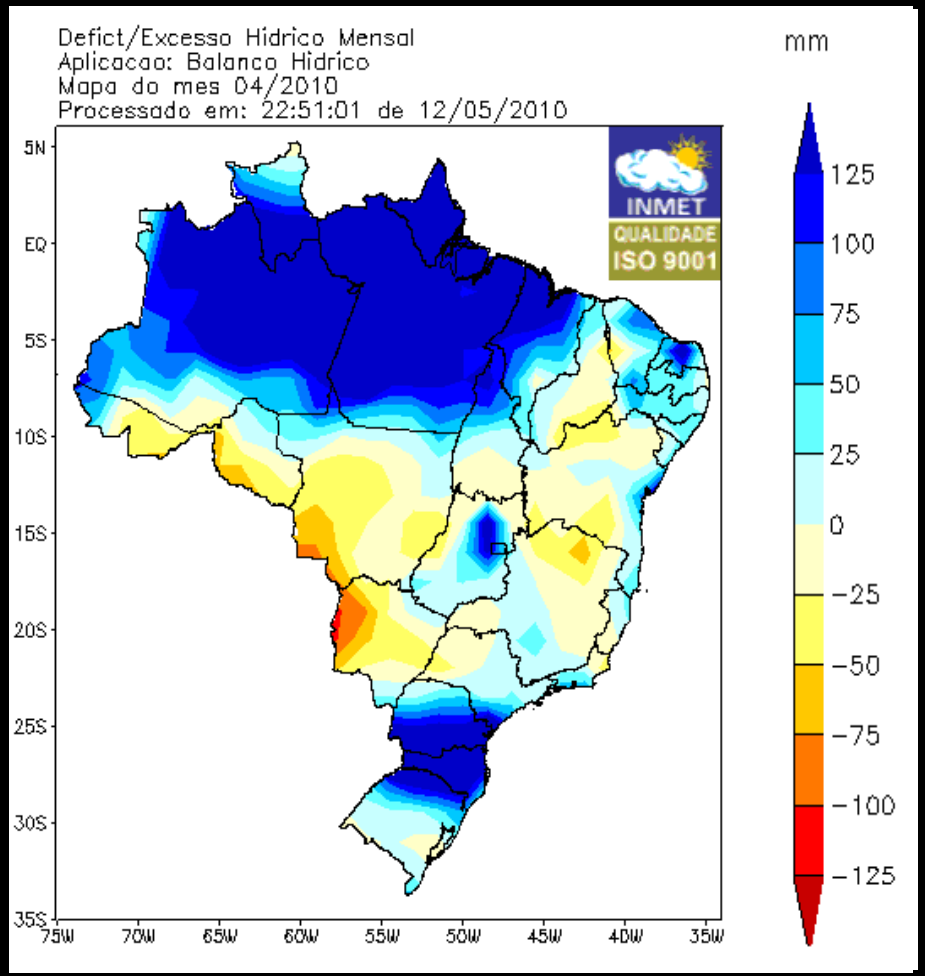


1990-91 → ETP = 510 mm / 2004-05 → ETP = 550 mm

Drought Monitoring

Climatological Water Balance Monitoring in Brazil (SWHC = 125cmm)





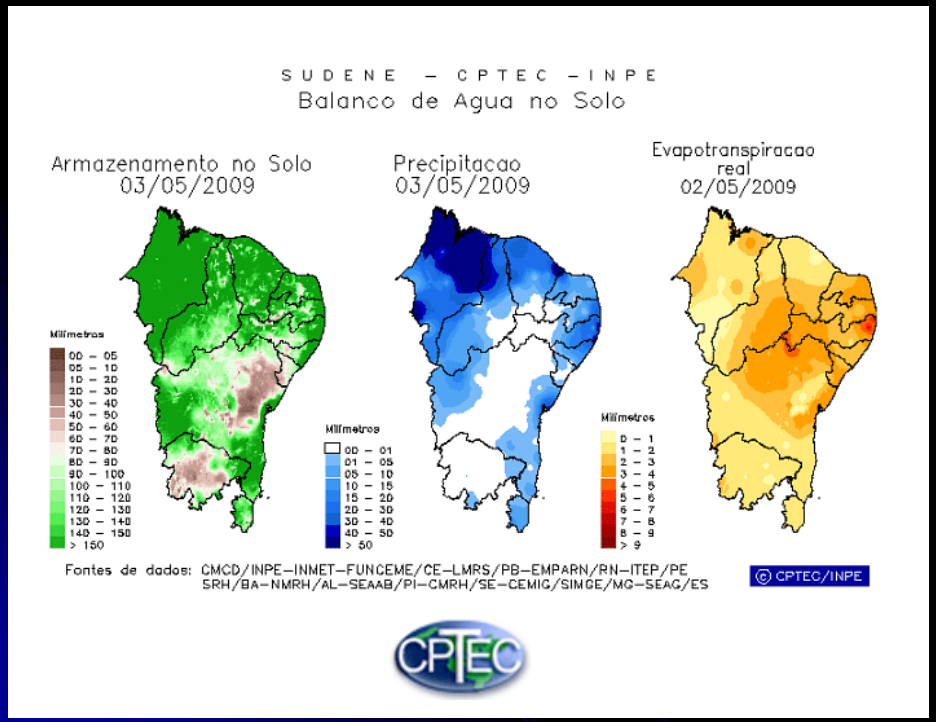
Drought Monitoring

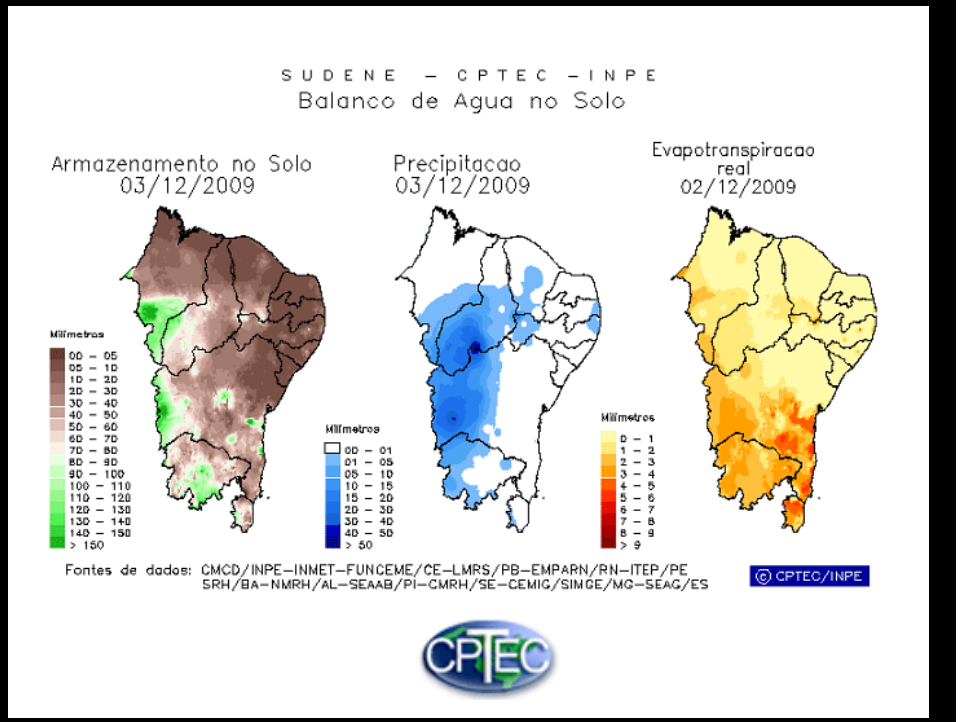
Other Agricultural Drought Indexes in Current Use

PROCLIMA – NE (Rainfall, Soil Moisture and Actual ET)

Water Balance based on

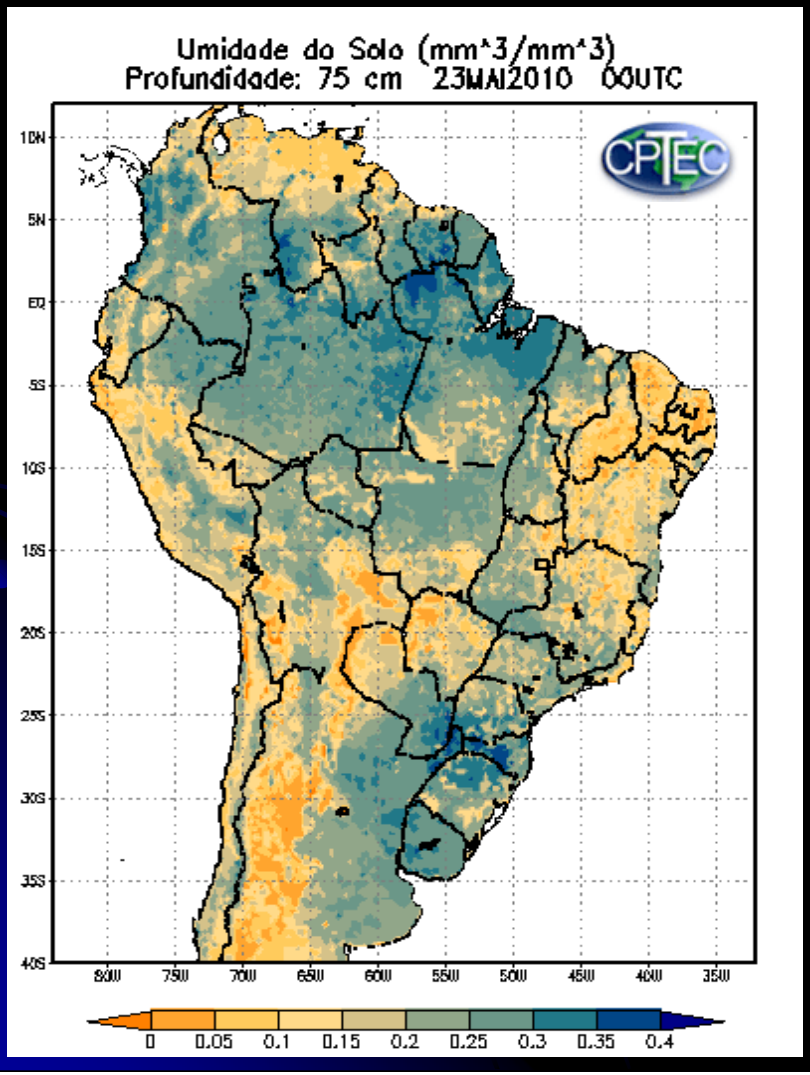
Pedo-transfer Functions / P-M ETo / Rainfall from 1000 rain-gauges





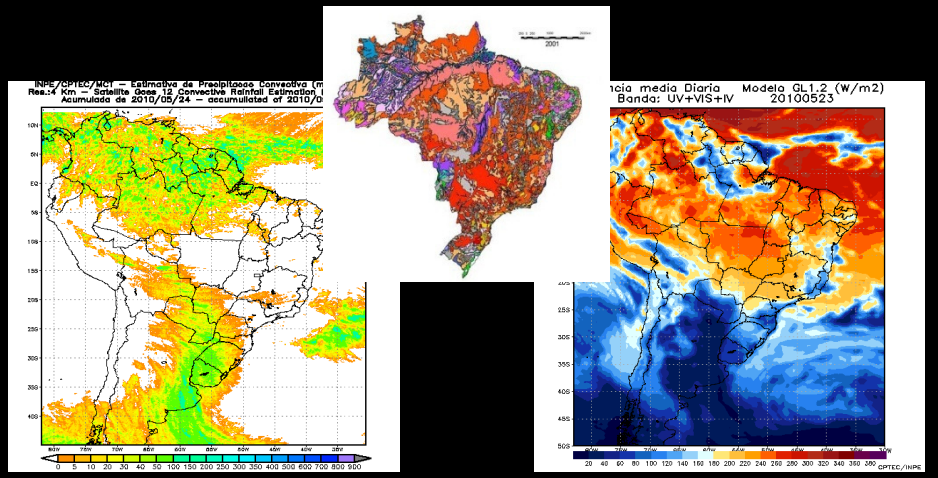
Drought Monitoring

Other Agricultural Drought Indexes in Current Use



Soil Moisture – estimated from satellite rainfall data applied to the Richards' Hydrological Model.

Pedo-transfer functions are used to characterize soil variability and ETo is estimated by Penman-Monteith Method

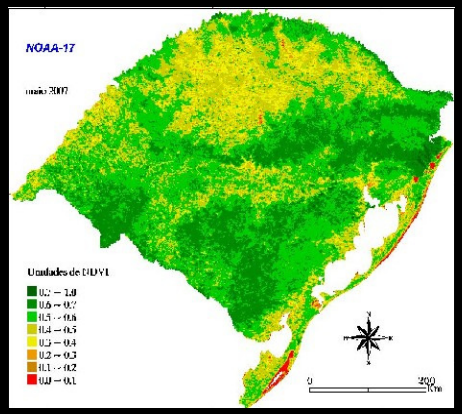


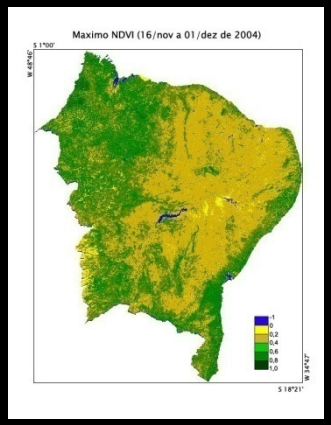
Drought Monitoring

Other Agricultural Drought Indexes in Current Use

NDVI Maps

The Division of Satellite Images from National Space Institute (INPE) delivers NDVI images for drought monitoring in a national and regional levels

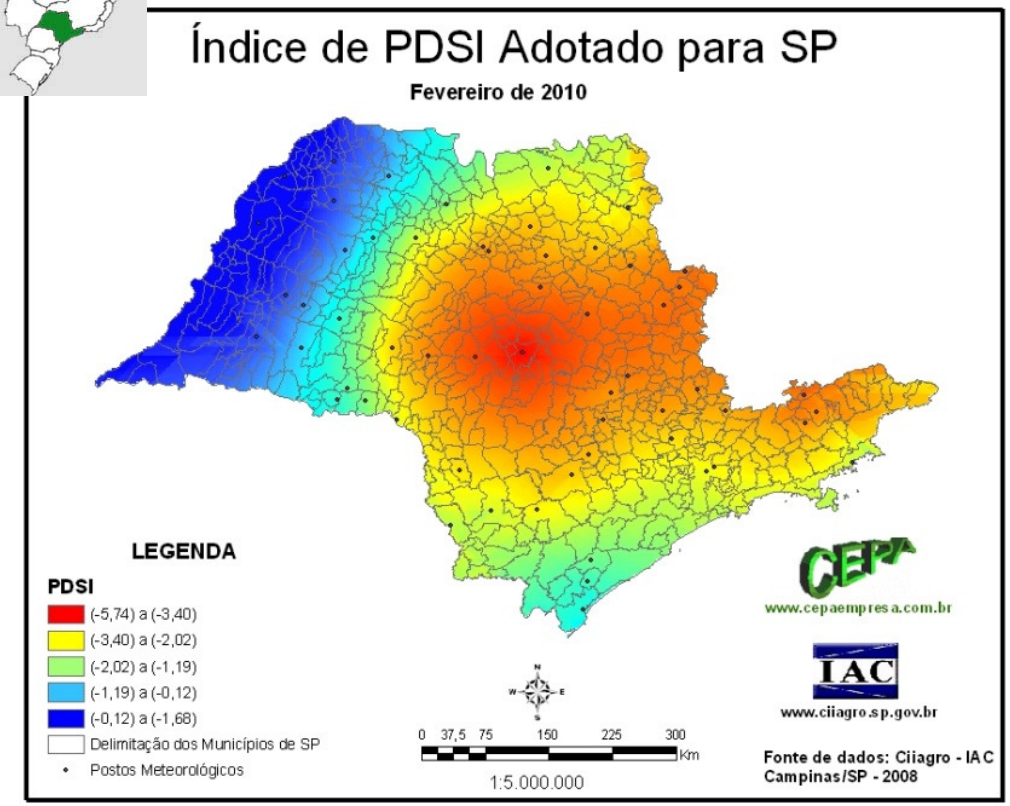




Other Agricultural Drought Indices in Current Use

Palmer Drought Severity Index Adapted to São Paulo State

PDSI-Adapted



≥ 3.00	Extremely wet
2.00 a 2.99	Very wet
1.00 a 0.99	Moderately wet
0.51 a 0.99	Beginning of wet period
0.50 a -0.50	Normal
-0.51 a -0.99	Beginning of dry period
-1.00 a -1.99	Moderately dry
-2.00 a -2.99	Very dry
≤ -3.00	Extremely dry

Blain & Brunini (2005, 2007)

INFOSECA

The main focus of the PDSI adjustment (PDSI adap) was the adaptation of the K factor and the Palmer's index final equation

Accumulated Drought Index

P & ETP Relationship	ISM
P >= 2 ETP	Wet (5)
ETP <= P < 2 ETP	Lightly wet (4)
½ ETP <= P < ETP	Normal (3)
0 < P <= ½ ETP	Lightly dry (2)
P = 0	Dry (1)

INFOSECA

$$ISMA = \frac{\sum ISM}{n \cdot 3 \cdot N}$$

ISMA	Wet/Dry Conditions
ISMA >= 1.50	Very wet
0.80 <= ISMA < 1.50	Wet
0.40 <= ISMA < 0.80	Lightly wet
0.20 <= ISMA < 0.40	Normal
0.04 <= ISMA < 0.2	Lightly dry
0.004 <= ISMA < 0.04	Dry
ISMA < 0.004	Very Dry

Accumulated Drought Index

ISMA	Wet/Dry Conditions
ISMA >= 1,50	Very wet
0,80 <= ISMA < 1,50	Wet
0,40 <= ISMA < 0,80	Lightly wet
0,20 <= ISMA < 0,40	Normal
0,04 <= ISMA < 0,2	Lightly dry
0,004 <= ISMA < 0,04	Dry
ISMA < 0,004	Very Dry

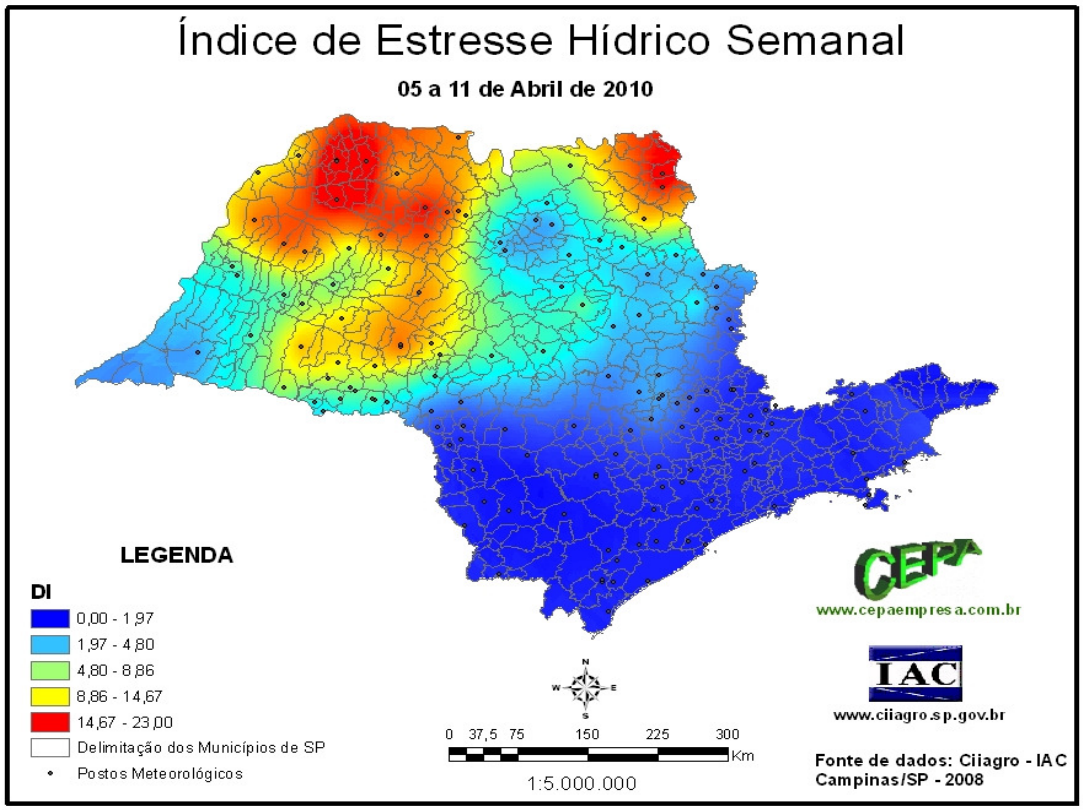
INFOSECA

Drought Conditions by Location

Condições Meteorológicas Atuais: 20/05/2010 - 23/05/2010		
Local	ISM	Condições
Região Administrativa: Araçatuba		
Andradina	1	Seco
Araçatuba	1	Seco
Auriflama	1	Seco
Buritama	1	Seco
Ilha Solteira	2	Ligeiramente Seco
Mirandópolis	1	Seco
Penápolis	1	Seco
Piacatu	1	Seco
Valparaíso	1	Seco
Região Administrativa: Barretos		
Bebedouro	4	Ligeiramente Úmido
Colina	4	Ligeiramente Úmido
Guaíra	4	Ligeiramente Úmido
Monte Azul Paulista	2	Ligeiramente Seco
Região Administrativa: Bauru		
Bauru	1	Seco
Jaú	1	Seco
Lins	1	Seco

Relative Water Deficiency Index

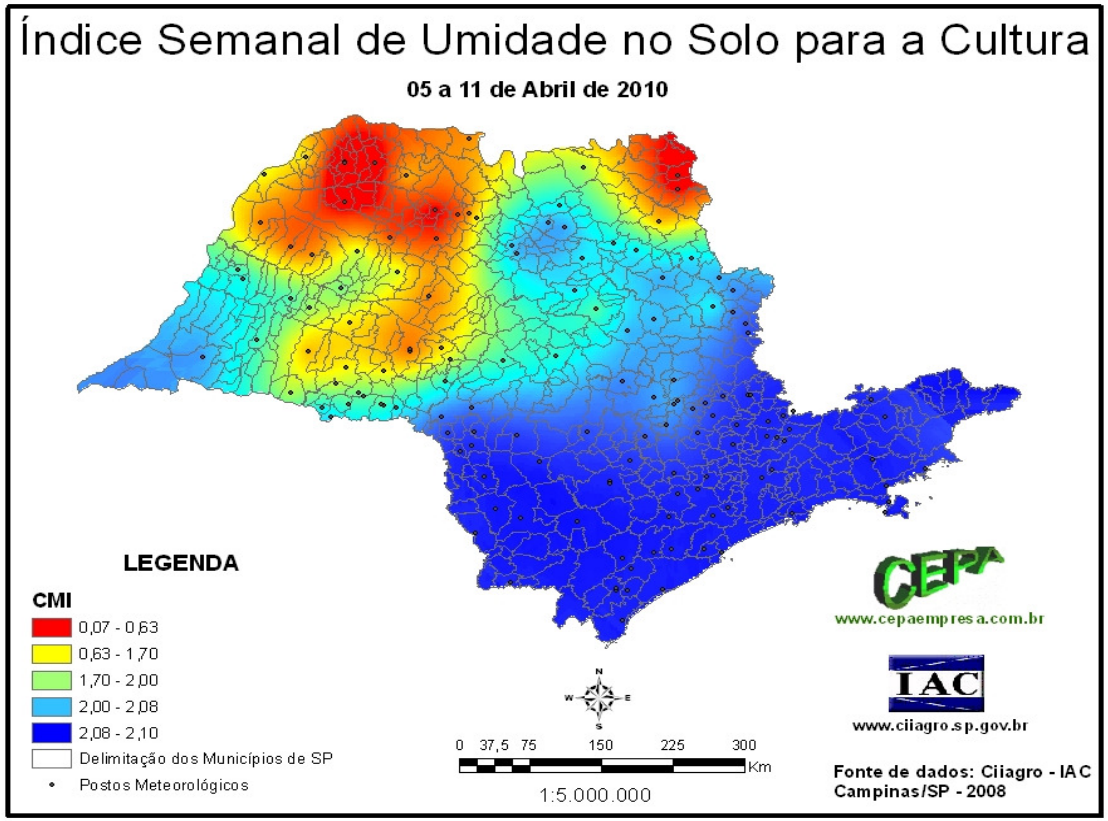
$$DI = (1 - ETa / ETP) * 100$$



INFOSECA

Crop Moisture Index

CMI = ETa observed – ETa expected



INFOSECA

Crop Water Development Index

$$CWDF = SWS / SWHC$$

SWS = Soil Water Storage → Climatological Water Balance

SWHC = Soil Water Holding Capacity → 25, 50, 75 and 100 mm

$$CWDI = (CWDF/0.40) - 1$$

INFOSECA

$$ACWDI = \sum (CWDI/n \,.\, 1.5)$$

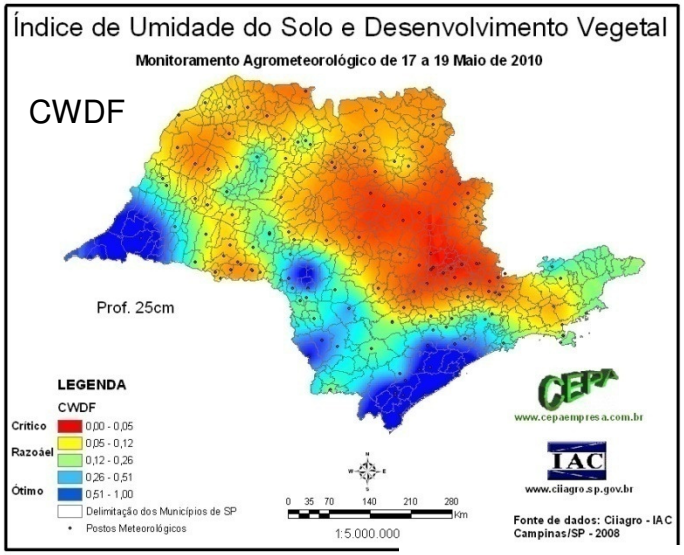
ACWDI	Crop Development Conditions
0.8 <= ACWDI <= 1	Very Good
0.6 <= ACWDI < 0.8	Good
0.4 <= ACWDI < 0.6	Reasonable
0.3 <= ACWDI < 0.4	Unfavorable
0.2 <= ACWDI < 0.3	Critical
0.1 <= ACWDI < 0.2	Severe
< 0.1	Extremely Severe

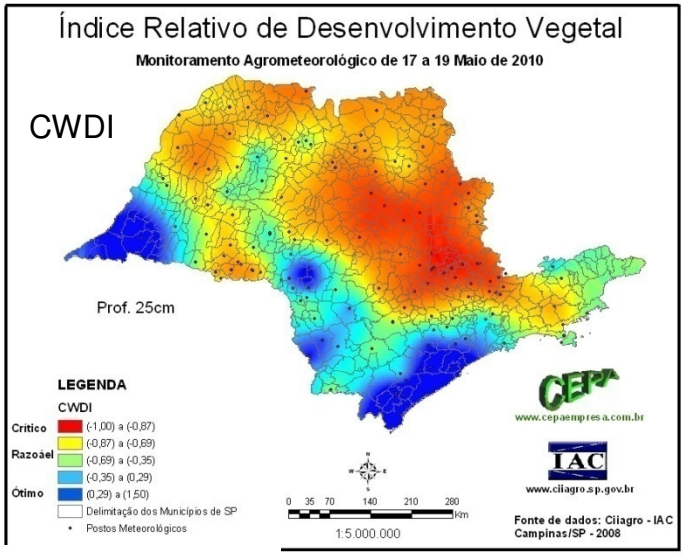
Crop Water Development Index

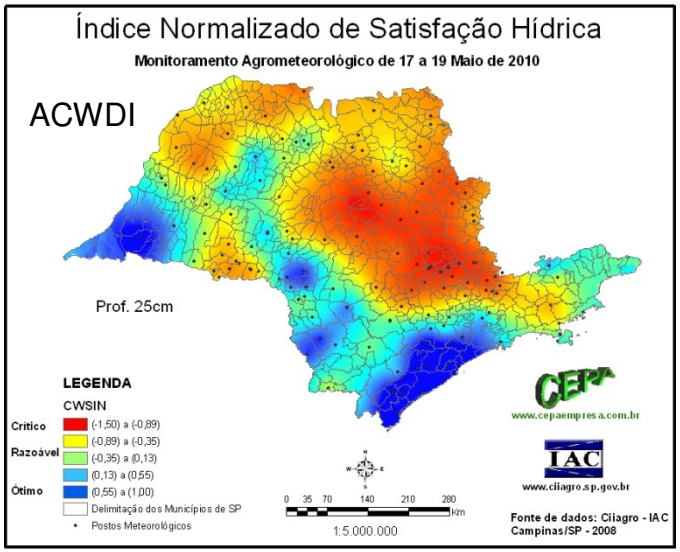
Condições Atuais de Desenvolvimento da Cultura: 20/05/2010 - 23/05/2010			
Local	Profundidade	CWDF	Condições
Adamantina	25	0	Criticas
Adamantina	50	0	Criticas
Adamantina	75	0	Criticas
Adamantina	100	0	Criticas
Amparo	25	0	Criticas
Amparo	50	0	Criticas
Amparo	75	0	Criticas
Amparo	100	0,03	Criticas
Andradina	25	0	Criticas
Andradina	50	0	Criticas
Andradina	75	0	Criticas
Andradina	100	0	Criticas
Araçatuba	25	0	Criticas
Araçatuba	50	0	Criticas
Araçatuba	75	0	Criticas
Araçatuba	100	0,17	Severas
Araraquara	25	0	Criticas
Araraquara	50	0	Criticas
Araraquara	75	0	Criticas
Araraquara	100	0	Criticas

INFOSECA

Crop Water Development Index





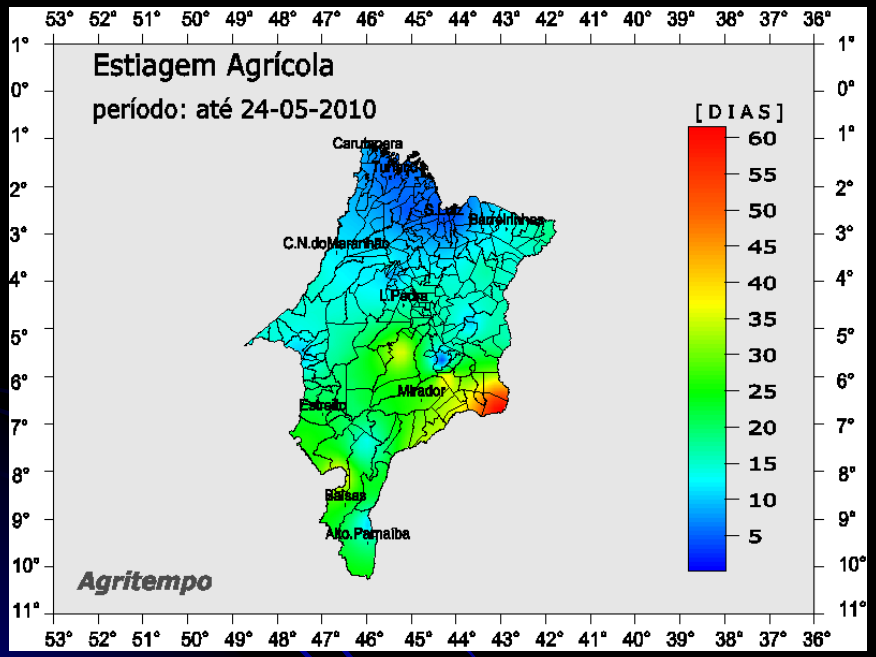


INFOSECA

Other examples of Agricultural Drought Monitoring in Brazil

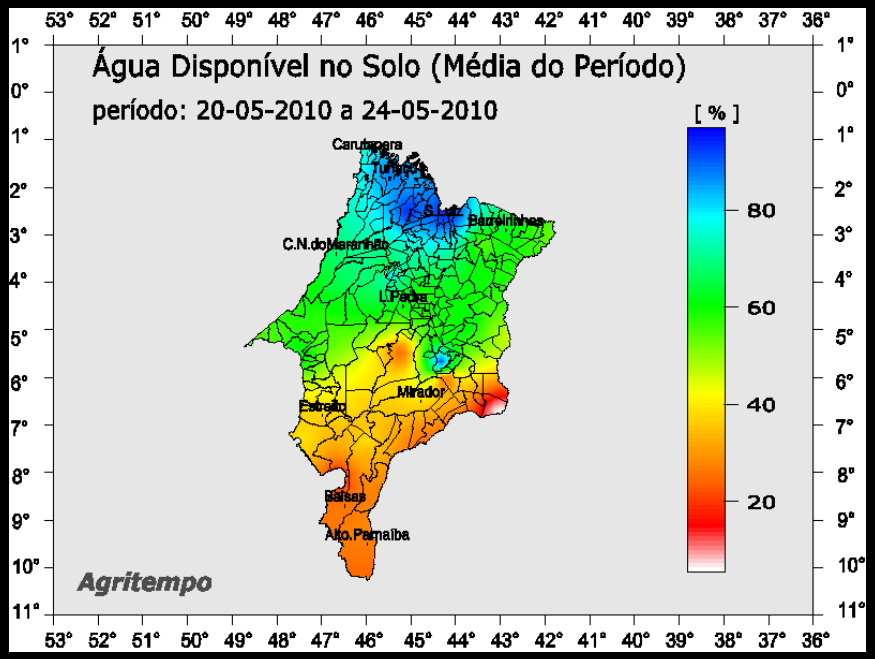
Agritempo

Embrapa



Number of Days with Rainfall below 5 mm

SWS / SWHC (%) T&M (1955) Model



Other examples of Agricultural Drought Monitoring in Brazil

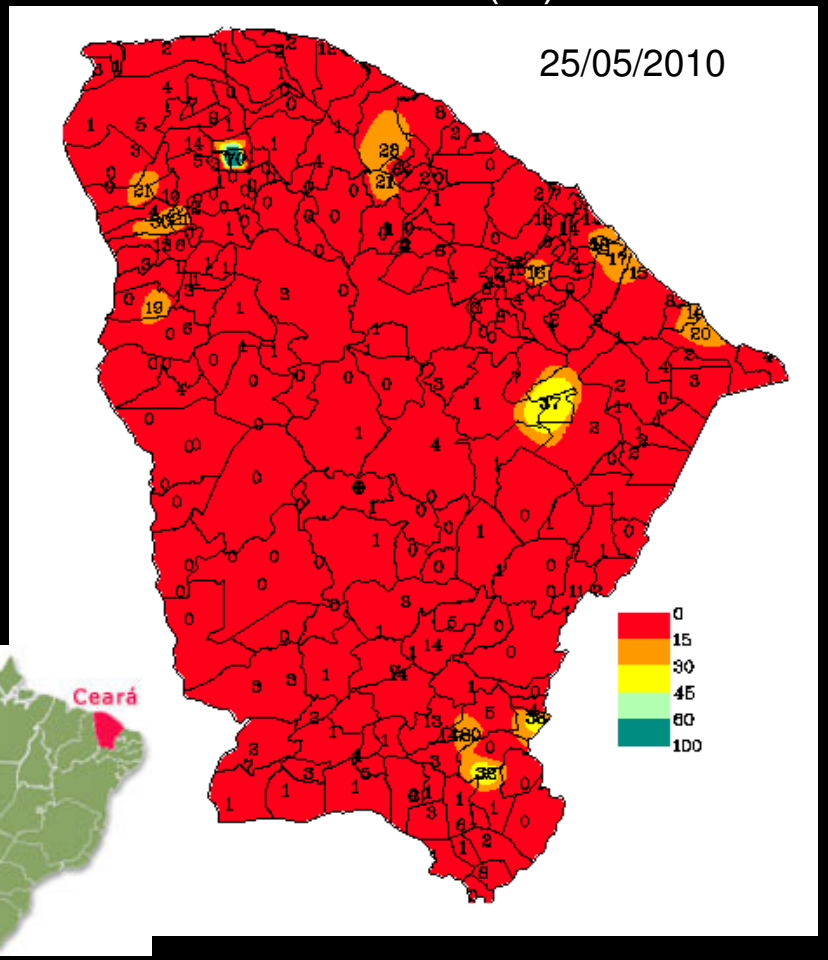
FUNCEME

State of Ceará Meteorological Service

MUSAG model

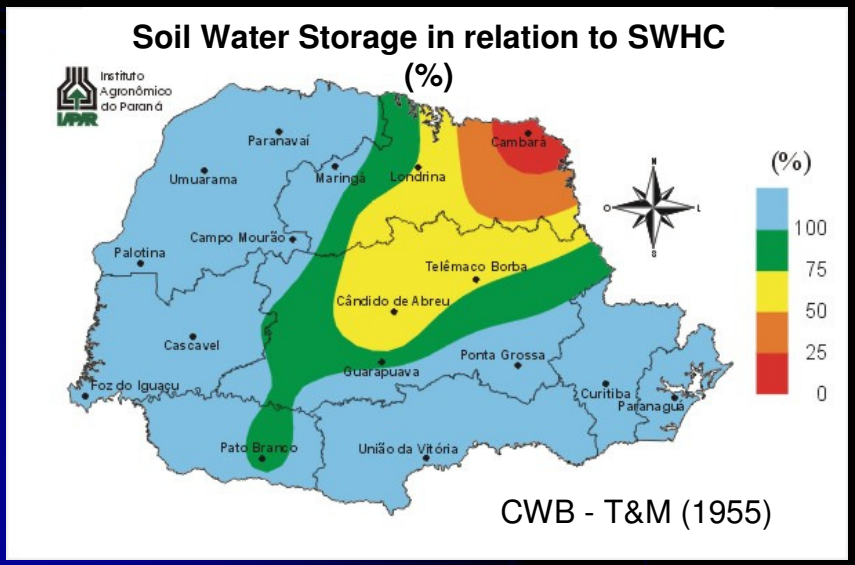
$Arm_f = Arm_i + Inf - Perc - Ev$

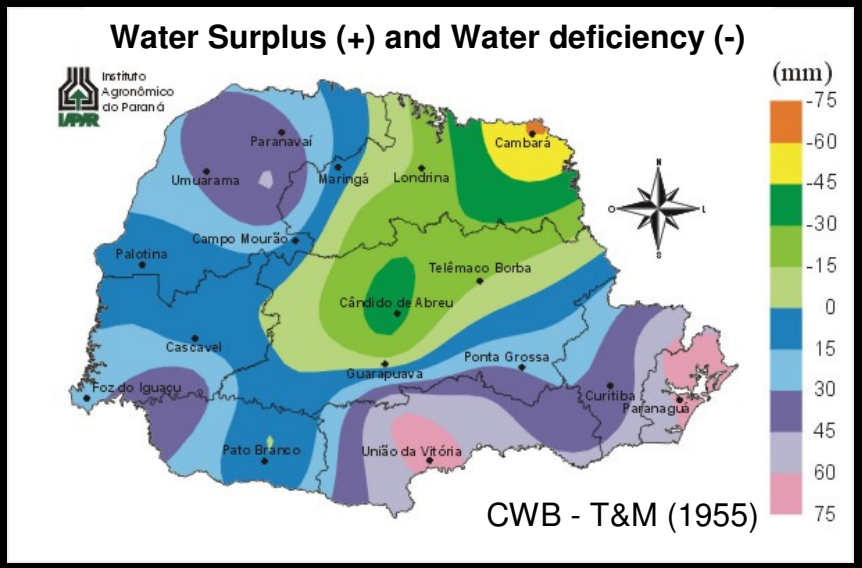
Soil Water Storage in relation to SWHC (%)



Other examples of Agricultural Drought Monitoring in Brazil

Agronomic Institute of Paraná





Other examples of Agricultural Drought Monitoring in Brazil

State of Goiás Meteorological & Hydrological Service

Sistema de Meteorologia e Hidrologia
SIMEHGO do Estado de Goiás

Tempo | Clima | Agricultura | Queimadas | Energia | Rede Observação | Imagens

Agricultura

Secretaria de Ciência e Tecnologia do Estado de Goiás

GOVERNO DO ESTADO DE GOIAS

HOME | VOLTAR | LOGIN | PUBLICAÇÕES | SIMEGO | LEGISLAÇÃO | PARCERIAS | LINKS | CONTATO

REDE DE OBSERVAÇÕES

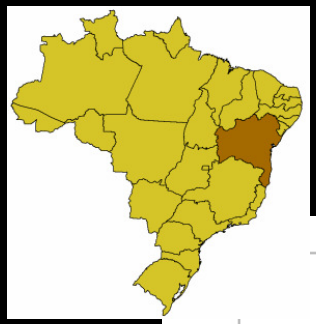
Climatological Water Balance (T&M, 1955)

Vianópolis - Estação Vianópolis I - Abril de 2010

Período desejado: Abril/2010 CAD (mm): 100 Acessar

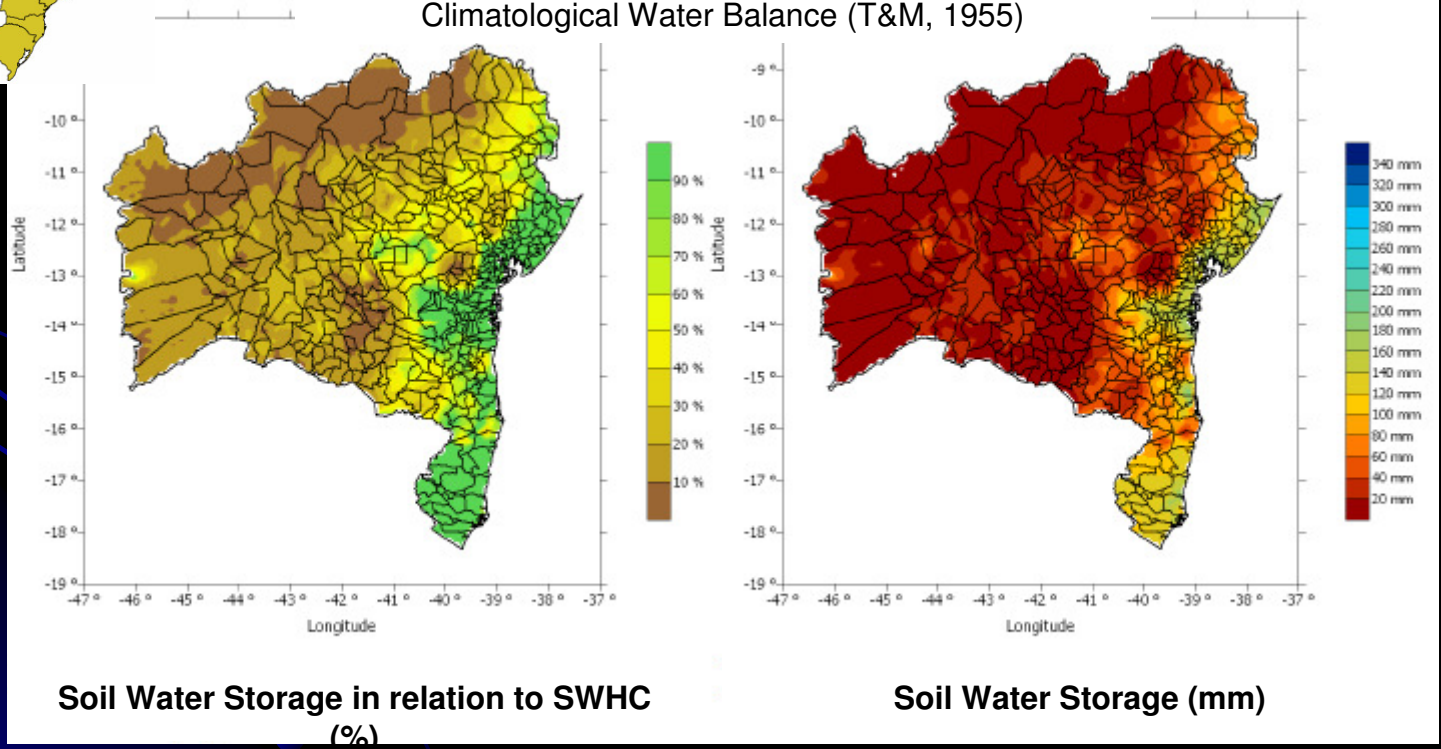
Mês	P	ETP	Dif	Neg	Negac	Arm	Alt	Etr	Defict	Excesso
Abril/2010	40.0	63.9	-23.9	23.9	23.9	100.0	0.0	40.0	23.9	0.0
Março/2010	7.8	47.6	-39.8	39.8	63.7	60.0	-39.8	47.6	0.0	0.0
Fevereiro/2010	0.0	57.3	-57.3	57.3	121.0	3.0	-57.3	57.3	0.0	0.0
Janeiro/2010	19.0	62.7	-43.7	43.7	164.6	0.0	-3.0	22.0	40.7	0.0
Dezembro/2009	81.8	88.2	-6.4	6.4	171.1	0.0	0.0	81.8	6.4	0.0
Novembro/2009	220.0	81.8	138.2	0.0	0.0	100.0	100.0	81.8	0.0	38.2
Outubro/2009	116.8	96.3	20.4	0.0	0.0	100.0	0.0	96.3	0.0	20.4
Setembro/2009	288.0	90.3	197.7	0.0	0.0	100.0	0.0	90.3	0.0	197.7
Agosto/2009	141.0	99.5	41.5	0.0	0.0	100.0	0.0	99.5	0.0	41.5
Julho/2009	78.2	86.1	-7.9	7.9	7.9	92.0	-7.9	86.1	0.0	0.0
Junho/2009	365.5	97.3	268.2	0.0	0.0	100.0	8.0	97.3	0.0	260.2
Maio/2009	13.8	72.6	-58.8	58.8	58.8	41.0	-58.8	72.6	0.0	0.0

cemba
CENTRO ESTADUAL DE METEOROLOGIA DA BAHIA



State of Bahia Meteorological Service

Climatological Water Balance (T&M, 1955)



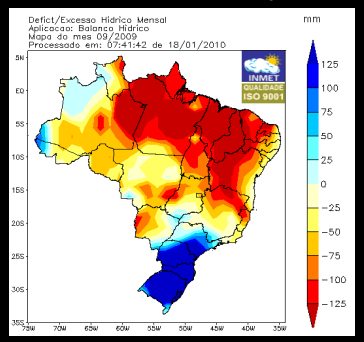
Soil Water Storage in relation to SWHC (%)

Soil Water Storage (mm)

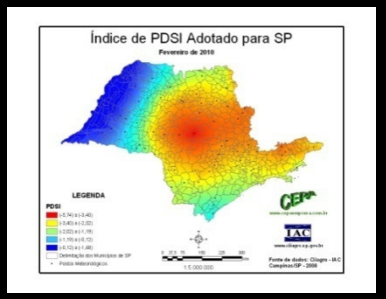
Water Balance based Drought Indexes

ETP & Climatological WB
(T&M, 1955)

Accumulated Water Deficiency



PDSI-Adapted



Strengths

P & ETP data

Easy to Apply

Easy to Understand

Does not require much computational power

Accumulated Drought Index

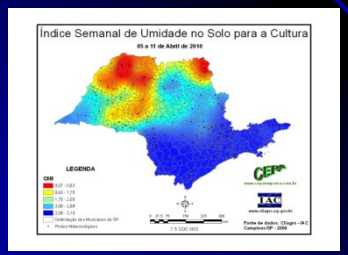
$$ISMA = \frac{\sum ISM}{n \,.\, 3 \,.\, N}$$

Crop Water Development Index

$$CWDF = SWS / SWHC$$

$$CWDI = (CWDF / 0.40) - 1$$

$$ACWDI = \sum (CWDI / n \,.\, 1.5)$$

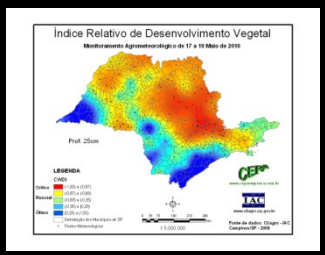


Relative Water Deficiency Index

$$DI = (1 - ETa / ETP) * 100$$

Crop Moisture Index

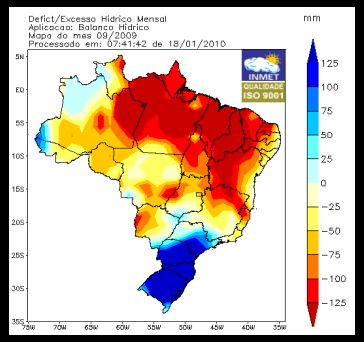
$$CMI = ETa_{observed} - ETa_{expected}$$



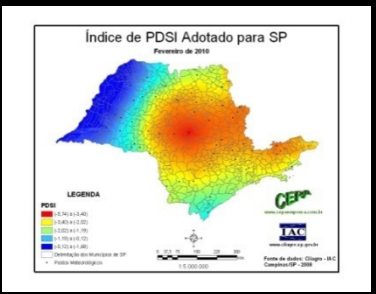
Water Balance based Drought Indexes

ETP & Climatological WB (T&M, 1955)

Accumulated Water Deficiency



PDSI-Adapted



Limitations

Depends on:

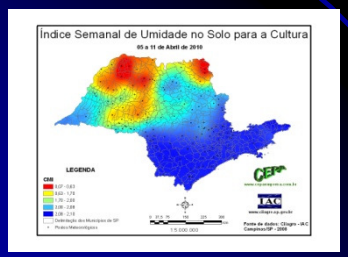
ETP method Adopted

SWHC

Crop type & phase Crop management

Accumulated Drought Index

$$ISMA = \frac{\sum ISM}{n \cdot 3 \cdot N}$$



Relative Water Deficiency Index

$$DI = (1 - ETa / ETP) * 100$$

Crop Moisture Index

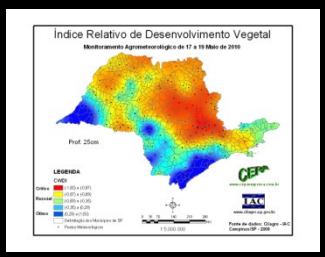
$$CMI = ETa_{observed} - ETa_{expected}$$

Crop Water Development Index

$$CWDF = SWS / SWHC$$

$$CWDI = (CWDF / 0.40) - 1$$

$$ACWDI = \sum (CWDI / n \cdot 1.5)$$



Strengths, Weaknesses and Limitations of Agricultural Drought Indexes in current use in Brazil

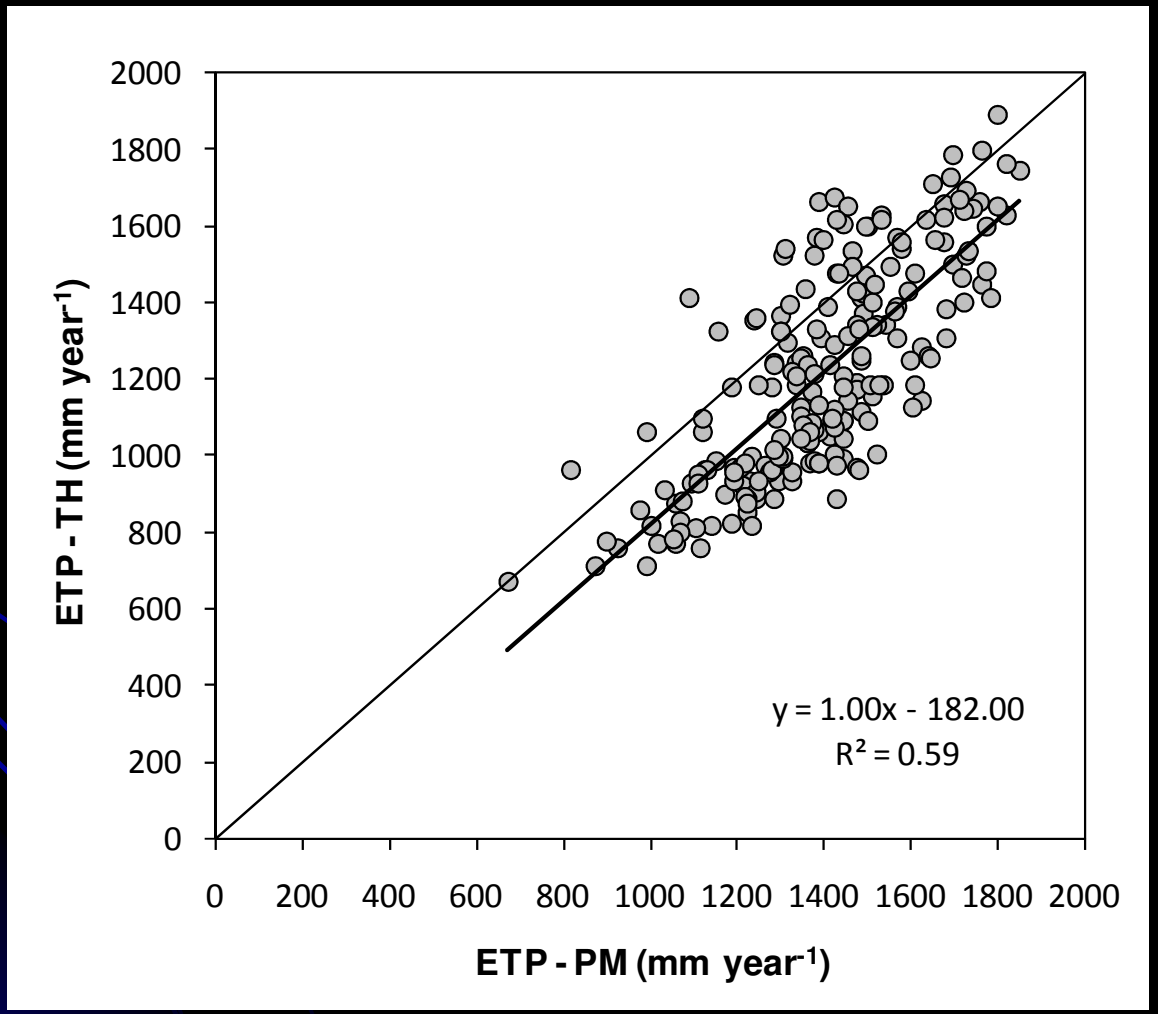
ETP method

Different ETP methods will result in different values for the same weather conditions. It will make Agricultural Drought Indexes vulnerable to this method, in terms of the right dimension of the drought index.

This is a problem when Penman-Monteith method can not be applied, due to lack of data. So Agricultural Drought Indexes based on ETP or ETR estimated by different methods are not comparable.

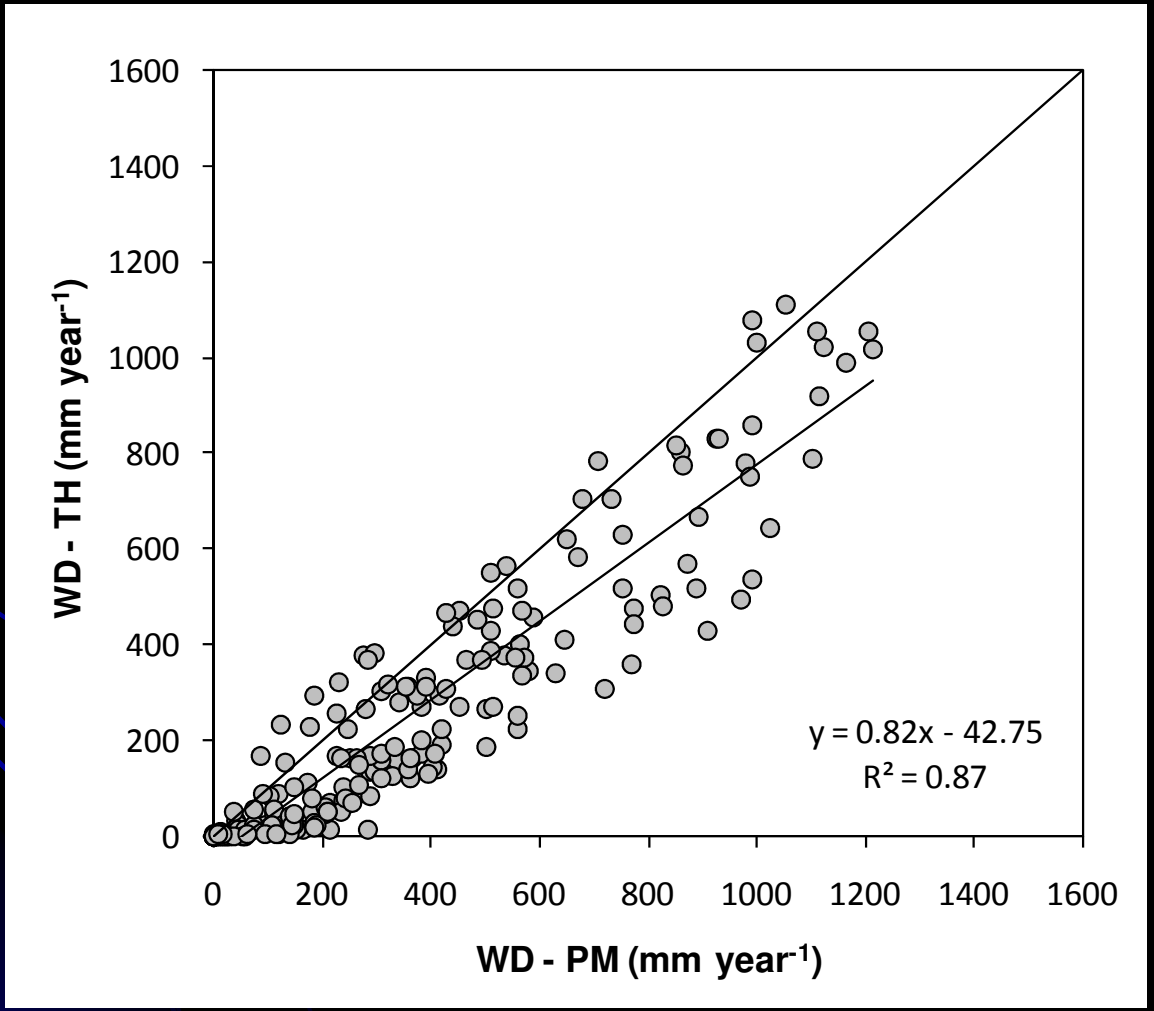
The Original Thornthwaite method normally underestimates ETP for Brazil, but it is the main method used, since requires only average temperature as input

Potential Evapotranspiration for Brazil Thornthwaite (TH) X Penman-Monteith (PM)



Water Deficiency for Brazil Thornthwaite

(TH) X Penman-Monteith (PM)



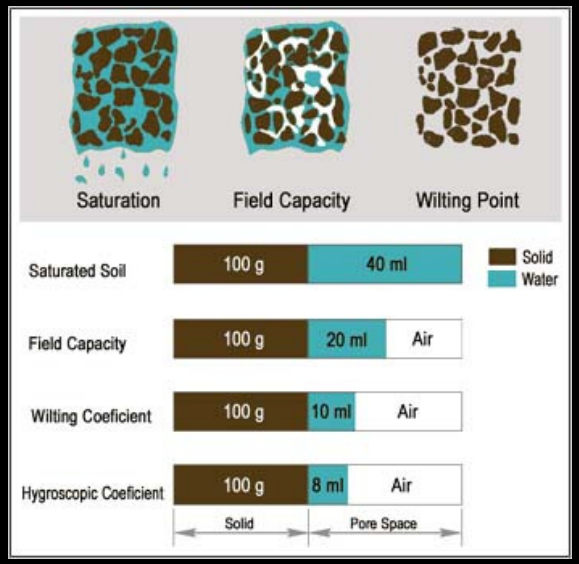
Strengths, Weaknesses and Limitations of Agricultural Drought Indexes in current use in Brazil

SWHC Adopted

SWHC = [(FC% - WP%)/100] * dg * ZR

Roots depth (mm)

Sandy Soil



Clay Soil

< SWHC >

SWHC Adopted

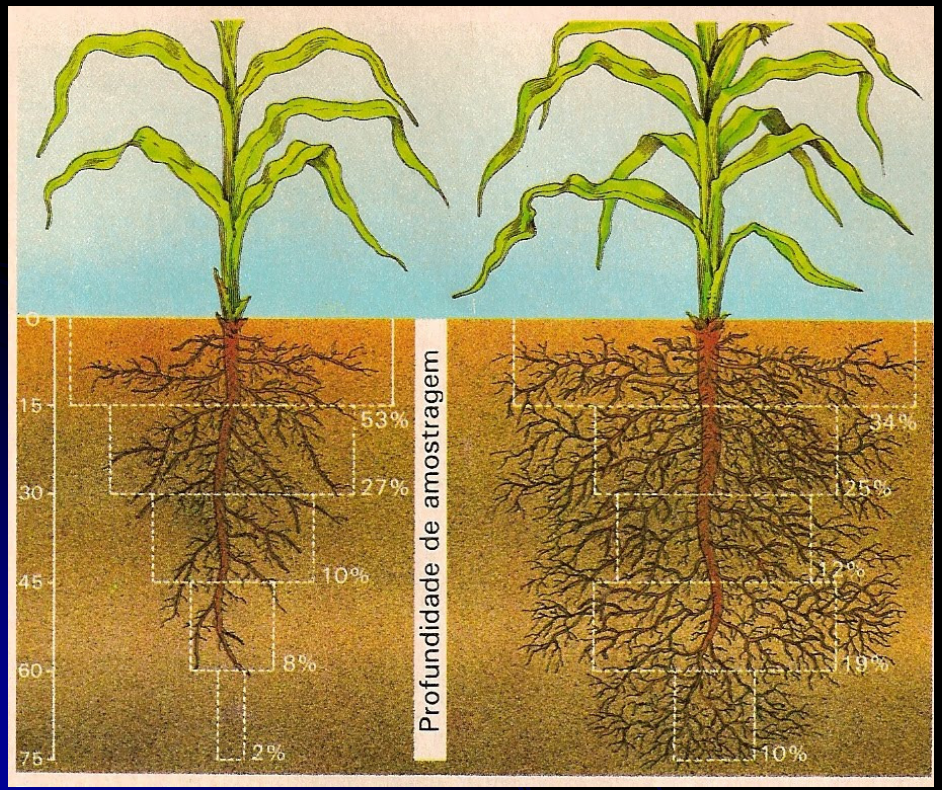
Roots Depth & Volume Effects

Roots depth and volume depend on the crop and soil physical & chemical conditions

SWHC Adopted

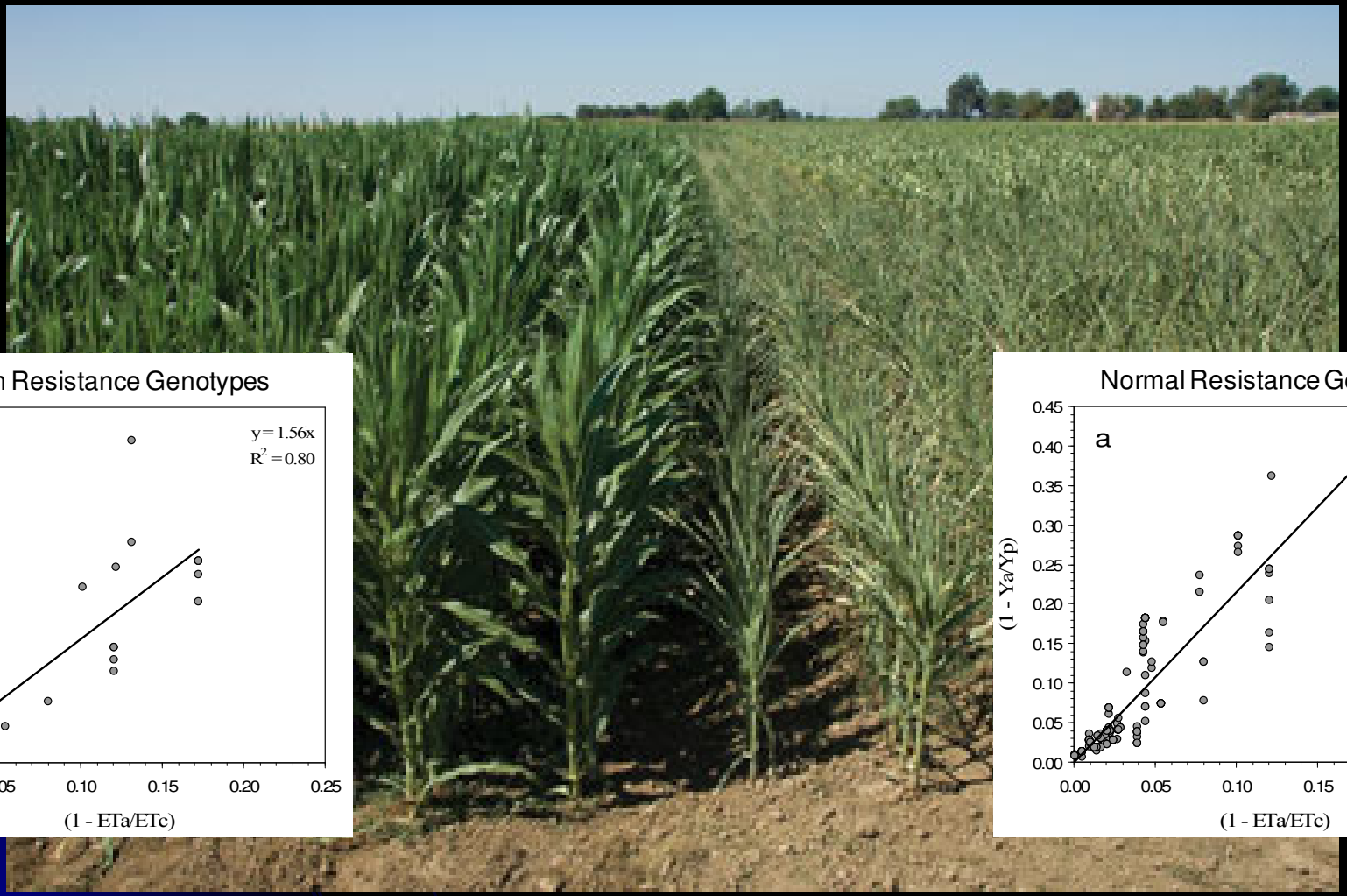
Roots Depth and Volume

Gipsum Effect on Roots Density



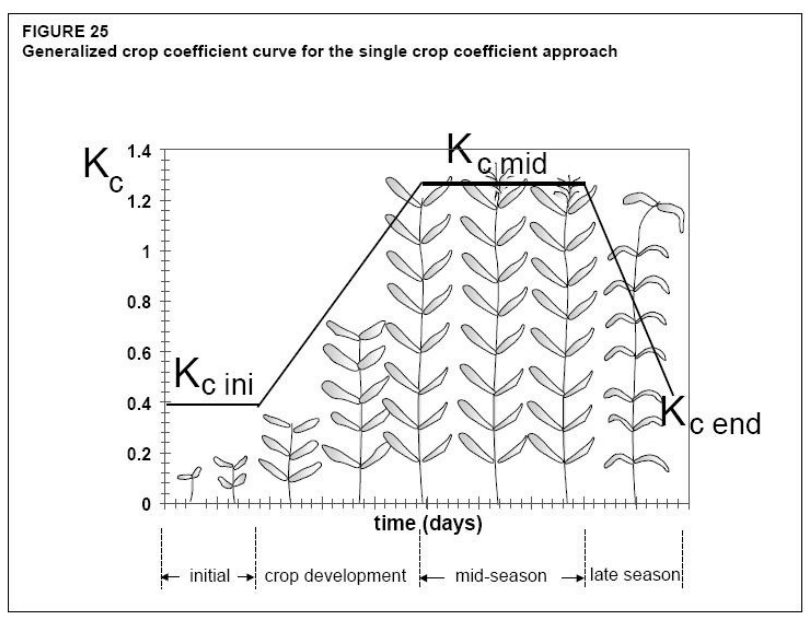
Soil Compactation Effect on Roots

Crop Type/Variety

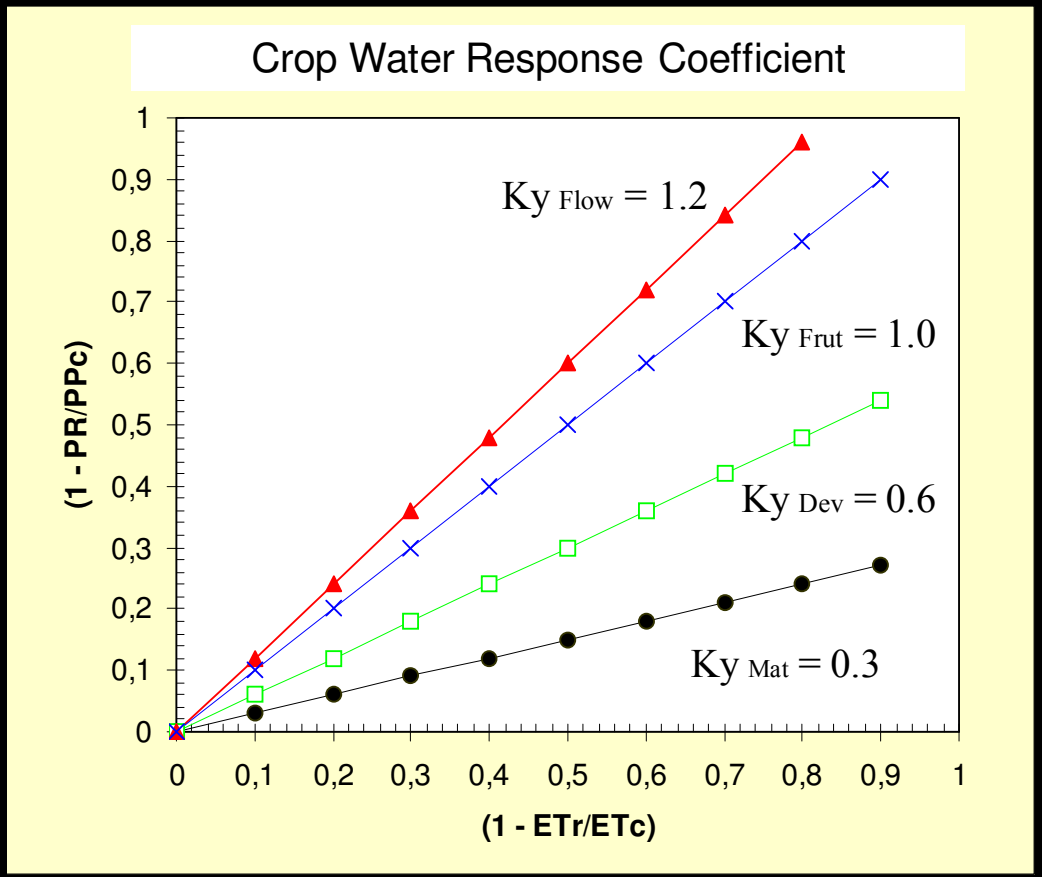


Crop Phase

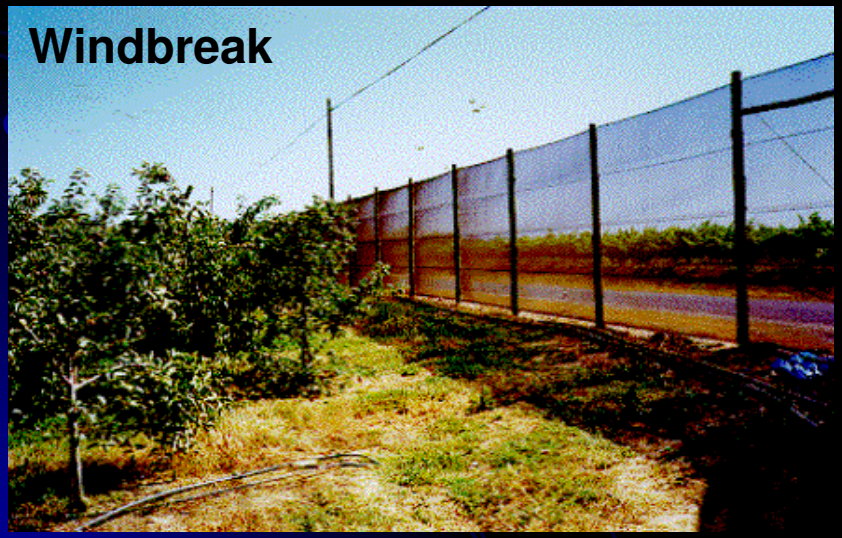
Crop coefficient (Kc)



Water deficit sensitivity coefficient (Ky)

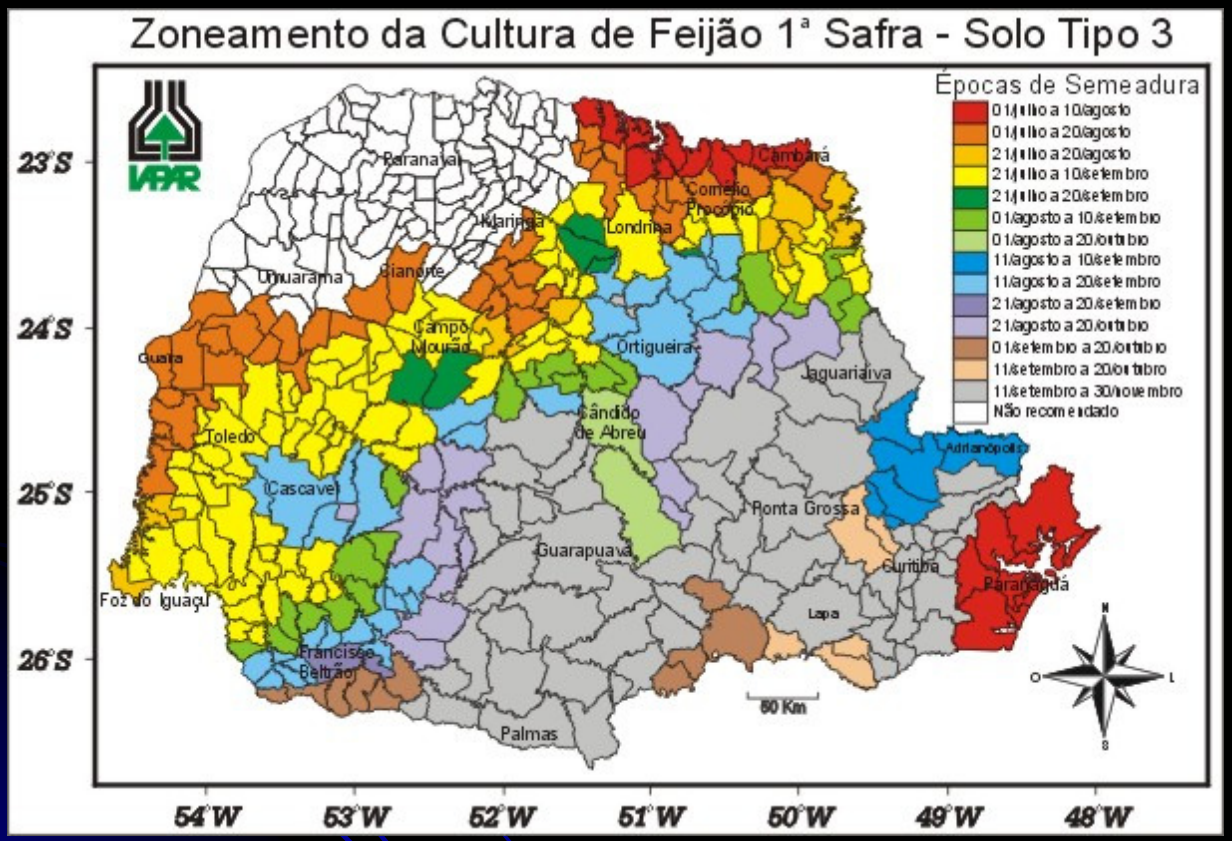


Crop Management



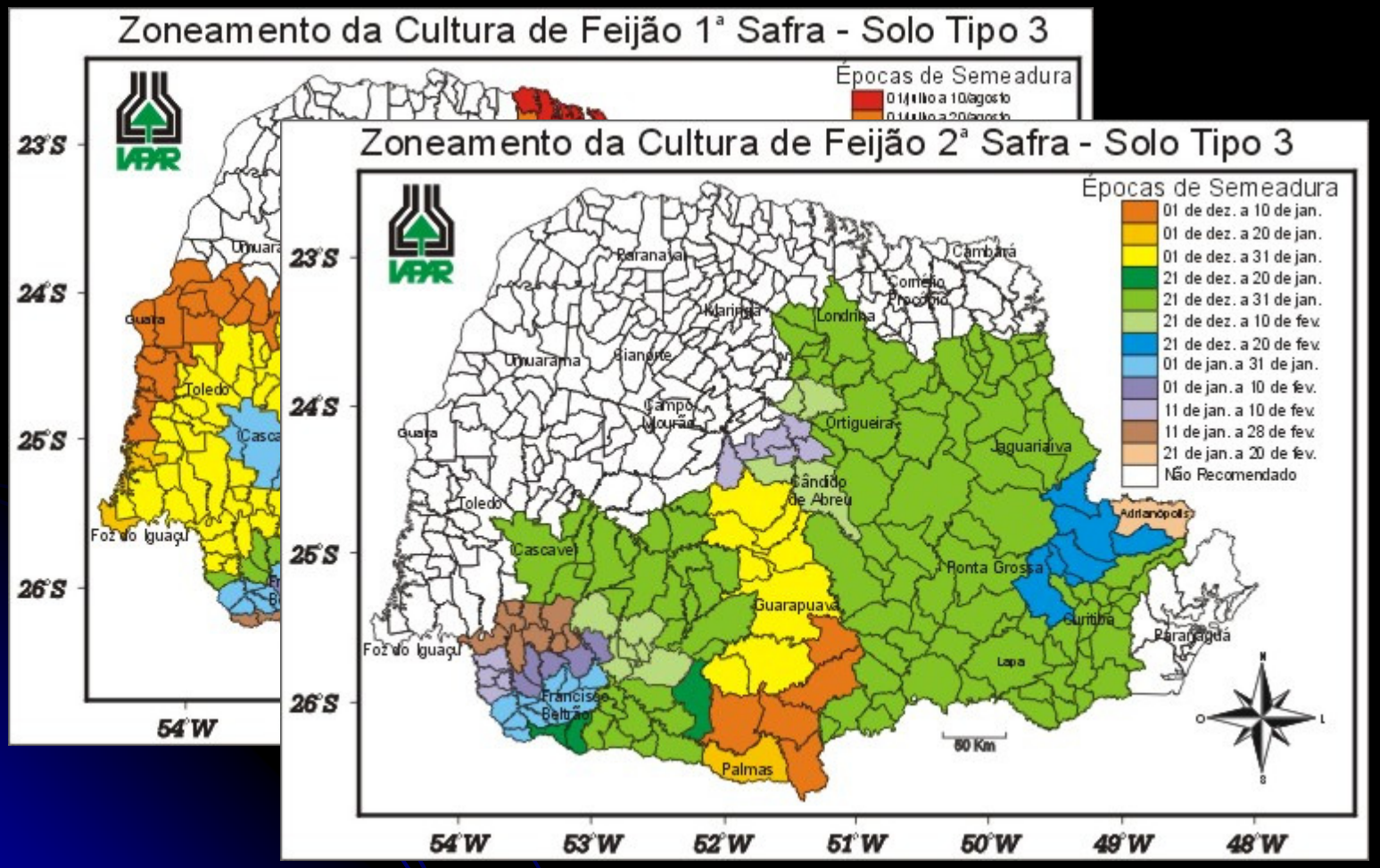
Crop Management

Sowing Dates



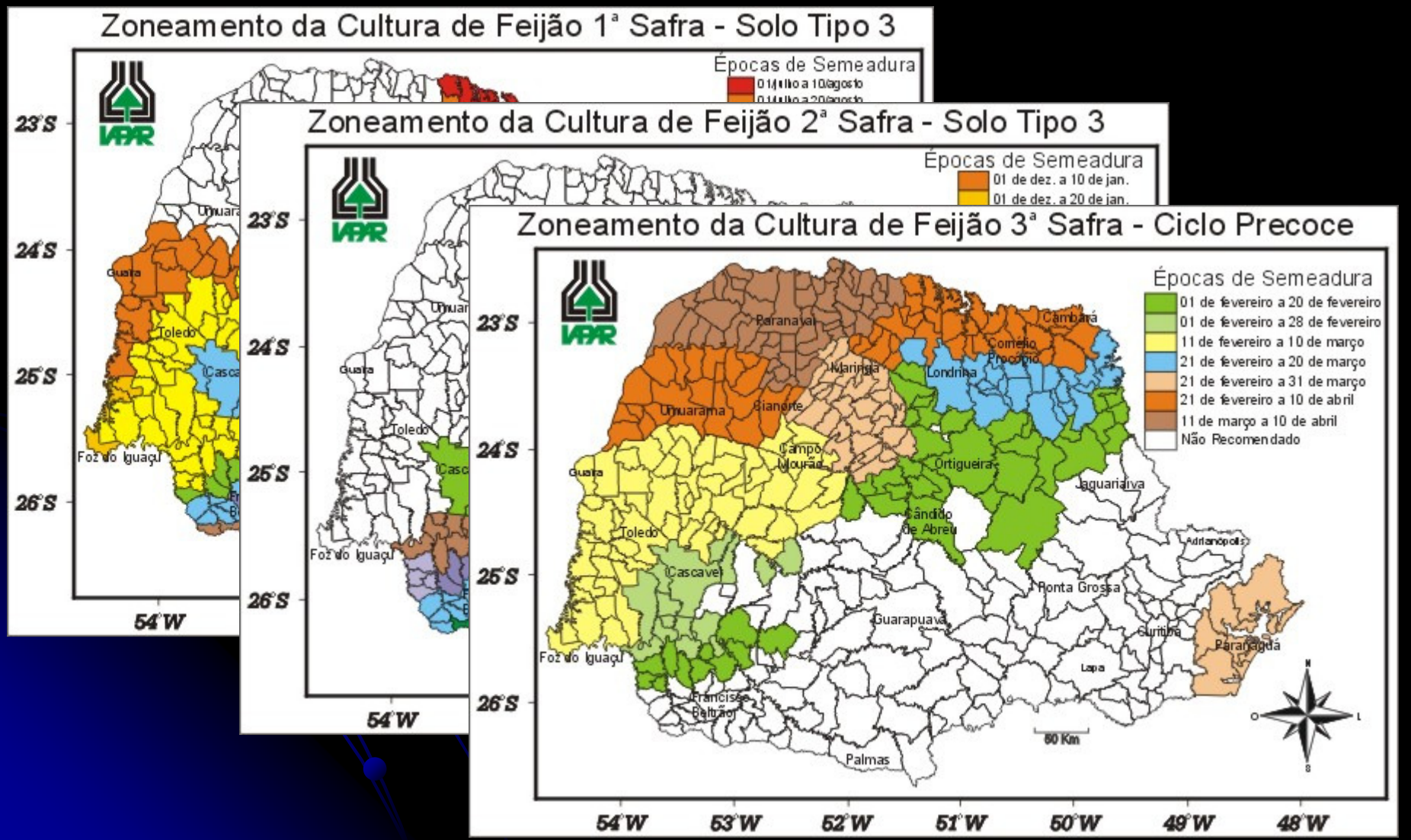
Crop Management

Sowing Dates



Crop Management

Sowing Dates



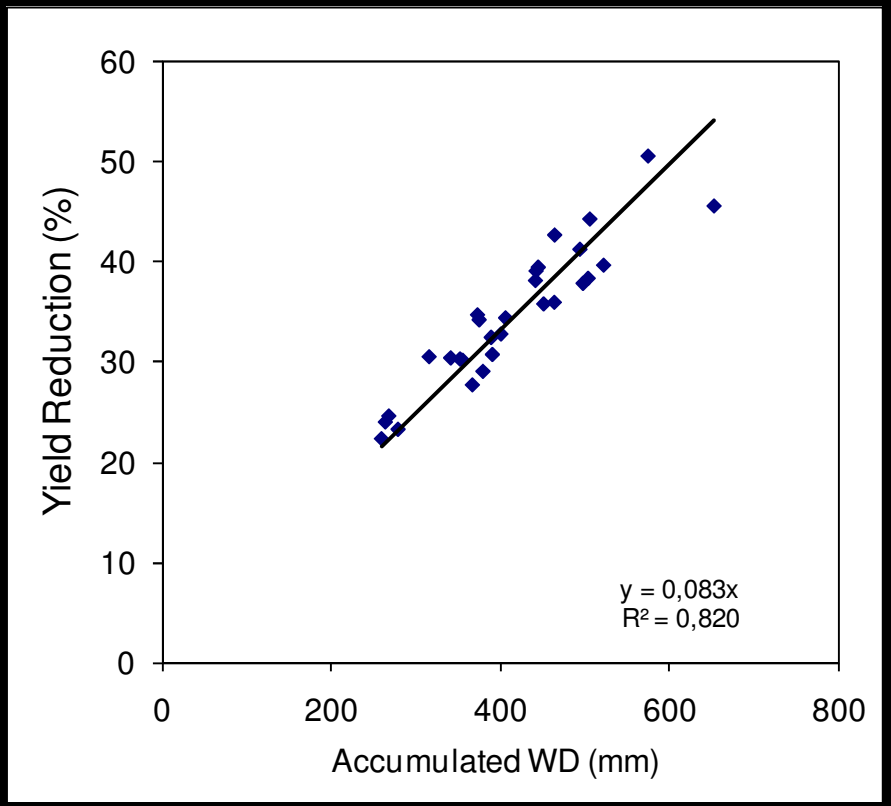
Final remarks

- In Brazil there are several National and Regional M&HSs with different ways to monitor drought under agricultural perspectives.
- Regional and National M&HSs estimate water balance by four different methods: T&M; MUSAG; Hydrological with satellite data; and Hydrological with observed info.
- However, the method of T&M (1955) is the most used by the National Met Service (INMET) and other Regional Agrometeorological Services in Brazil.
- In the state of São Paulo, several Agricultural Drought Indexes are in use, but the majority of them are based on Thornthwaite ETP and/or T&M Water Balance data.

Final remarks

√ Agricultural Drought Indexes, based on ETP, P and WB outputs (ETR or WD), are expected to have better relationships with crop yield losses than meteorological drought indexes, based only on rainfall.

Sugarcane Crop Yield Reduction as a function of Accumulated WD during the growing season



Final remarks

- Even considering the strengths of the WB based Agric Drought indexes, the WB, determined by any method, will depend on some critical factors, as ETP method, SWHC adopted, crop/variety type and phase, and crop management.

- These factors will lead to different impacts of a given drought to the crops during the growing season.

- In this way, what is better, to make the Agricultural Drought Indexes GENERAL or VERY SPECIFIC ???

- Considering the complexity of the agriculture, mainly in the tropical countries, would be possible the M&HSs provide VERY SPECIFIC drought indexes ??? How to do that, using complex indexes or crop simulation models ???

Thanks Gracias Merci Obrigado

Main building of ESALQ/USP, in Piracicaba, Brazil

Prof. Dr. Paulo Cesar Sentelhas
Dept. of Biosystem Engineering – ESALQ/USP
Agrometeorology Group
Tel (19) 3429-4283 (Ext. 225)
E-mail: pcsentel@esalq.usp.br